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Silica-Rich Sands and Aggregate Resource Deposits, Western Newfoundland

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CONTENTS

ABSTRACT v

INTRODUCTION 1
- Cement Making 2
- Cement Making at the North Star Cement Plant 5
- Previous Work 7

SILICA-RICH SAND PROJECT 8
- Field Program 8
- Data Analyses 8

RESOURCE AREAS 9
- Humber River 10
- Matthews Brook 11
- Little Rapids 11
- North Harbour - Grand Lake 12
- Dancing Point 12
- Reidville 13
- Rocky Brook 14
- Junction Brook 15
- Pasadena 17
- Hughes Brook 17
- North Brook 19
- Other Deposits 20

TRUCKING DISTANCE 20

SUMMARY 21

ACKNOWLEDGMENTS 23

REFERENCES 23

LIST OF FIGURES i

LIST OF TABLES iii

List of Figures

Figure 1. General location map showing silica-rich sand deposits sampled in western Newfoundland.

Figure 2. Silica-rich sand deposits at Humber Village, Little Rapids and Matthews Brook.

Figure 3. Cumulative graph showing averaged particle-size distribution in the Humber River deposit.

Figure 4. Cumulative graph showing averaged particle-size distribution in the Matthews Brook deposit.

Figure 5. Cumulative graph showing particle-size distribution in the Little Rapids deposit.

Figure 6. Silica-rich sand deposit near North Harbour.

Figure 7. Cumulative graph showing particle-size distribution in the North Harbour deposit.

Figure 8. Silica-rich sand deposit near Dancing Point.

Figure 9. Cumulative graph showing averaged particle-size distribution in the Dancing Point deposit.

Figure 10. Silica-rich sand deposits near Reidville, Rocky Brook, Junction Brook and the Deer Lake airport.

Figure 11. Cumulative graph showing averaged particle-size distribution in the Reidville deposit.

Figure 12. Cumulative graph showing averaged particle-size distribution in the Rocky Brook deposit.

Figure 13. Cumulative graph showing averaged particle-size distribution in Zone 1 at Junction Brook.

Figure 14. Cumulative graph showing averaged particle-size distribution in Zone 2 at Junction Brook.

Figure 15. Cumulative graph showing averaged particle-size distribution in Zone 3 at Junction Brook.

Figure 16. Silica-rich sand deposit near Pasadena.

Figure 17. Cumulative graph showing particle-size distribution in the Pasadena deposit.

Figure 18. Silica-rich sand deposits at Hughes Brook.

Figure 19. Cumulative graph showing averaged particle-size distribution in Deposit 1 at Hughes Brook.

Figure 20. Cumulative graph showing averaged particle-size distribution in Deposit 2 at Hughes Brook.

Figure 21. Cumulative graph showing averaged particle-size distribution in Deposit 3 at Hughes Brook.

Figure 22. Cumulative graph showing averaged particle-size distribution in Deposit 4 at Hughes Brook.

Figure 23. Silica-rich sand deposit at North Brook.

Figure 24. Cumulative graph showing averaged particle-size distribution in the North Brook deposit.

List of Tables

Table 1. Geochemical constraints for sand used in cement production.

Table 2. Results of Corner Brook shale survey (complied by Dean and Meyer, 1985).

Table 3. Average geochemical analyses of samples collected in silica-rich sand deposits in western Newfoundland.

Table 4. Aggregate summary of silica-rich sand deposits in western Newfoundland.

Table 5. Geochemical results of sampled material at Humber Village.

Table 6. Particle-size analyses of sampled material at Humber Village.

Table 7. Geochemical results of sampled material near Matthews Brook.

Table 8. Particle-size analyses of sampled material near Matthews Brook.

Table 9. Geochemical results of sampled material at Little Rapids.

Table 10. Particle-size analyses of sampled material at Little Rapids.

Table 11. Geochemical results of sampled material near North Harbour.

Table 12. Particle-size analyses of sampled material near North Harbour.

Table 13. Geochemical results of sampled material near Dancing Point.

Table 14. Particle-size analyses of sampled material near Dancing Point, (1982 sample data collected by F. T. Kirby).

Table 15. Geochemical results of sampled material near Reidville.

Table 16. Particle-size analyses of sampled material near Reidville.

Table 17. Geochemical results of sampled material near Rocky Brook.

Table 18. Particle-size analyses of sampled material near Rocky Brook.

Table 19. Geochemical results of sampled material near Junction Brook.

Table 20. Particle-size analyses of sampled material near Junction Brook.

Table 21. Geochemical results of sampled material near Pasadena.

Table 22. Particle-size analyses of sampled material near Pasadena.

Table 23. Geochemical results of sampled material near Hughes Brook.

Table 24. Particle-size analyses of sampled material near Hughes Brook.

Table 25. Geochemical results of sampled material near North Brook.

Table 26. Particle-size analyses of sampled material near North Brook.

Table 27. Distance of silica-rich sand deposits from the North Star Cement Company, Corner Brook.

Table 28. Total cost and average cost of truck transport of sand, gravel, and crushed materials at various distance for Newfoundland and Labrador, 1977 (compiled by Carter, 1981).

ABSTRACT

A project was undertaken in 1986 to locate sand deposits, having a high-silica and low-alumina, magnesium and alkali content. A high sand, low gravel and silt-clay content would add to the exploitation potential of such a deposit. These deposits would be used by the North Star Cement Company of Corner Brook, Newfoundland to replace part or all shale presently being used in the production of cement. The shale has a variable geochemistry, which is stabilized in their cement product by the silica-rich sand. Previous efforts to locate another high-quality shale deposit near Corner Brook have been unsuccessful. However, this study has located a number of potential silica-rich sand deposits; those with the most economic potential are situated near Dancing Point, Hughes Brook and Junction Brook. These deposits should supply adequate reserves to meet the long-term requirements of the North Star Cement Company.

INTRODUCTION

In 1986, a project was carried out by the Department of Mines and Energy in conjunction with the North Star Cement Company of Corner Brook, to locate a deposit of silica-rich sand in the area between Flat Bay and Deer Lake (Figure 1). This sand deposit would have geochemical characteristics compatible for use with shale and limestone or replace the shale content in the production of cement. The shale deposit currently in use has a variable geochemistry and needs a high silica, low alumina material to increase cement quality.

Increased interest in the cement industry will probably result from the demand for cement in the development of the offshore oil industry, especially in the construction of offshore oil-production platforms. Each gravity-based platform will require up to 160,000 m^3 of concrete, depending upon platform design (Steer, 1986). The associated impacts of offshore development upon infrastructure, and the industrial, commercial and residential needs of the province may be expected to dramatically increase the demand for portland cement.

Portland cement, often referred to simply as cement because of its predominance over other cements, is one of todays most widely used industrial materials. Between 1950 and 1979, cement production in the world registered more than a six-fold increase, from 133 million tonnes to 860 million tonnes (Ghosh, 1983) and up to approximately one billion tonnes in 1985 (Chatterjee 1983). This increase in cement production resulted from technological improvements in the cement manufacturing process and from various devices for energy economy and conservation including; low-temperature manufacture of cement

clinker, improved utlization of heat from the kiln gases and the use of low grade fuels (which are unsuitable for other purposes and might even be considered waste products) (Gutcho, 1980). The predominance of Portland cement over other cements is due to the wide range of raw materials that can be used in its production; also it is generally much cheaper and it can be used for a wider variety of purposes.

Portland cement is a fine grained inorganic material with a surface area of 225 to 450 m^2/kg depending on the type of cement produced (Bye, 1983). When mixed with water, it binds together solid particles of fine and coarse aggregate (sand and gravel or crushed rock) by transforming from a plastic state into a dense coherent mass to form concrete. It steadily increases in compressive strength by dehydration of water.

Cement Making

The manufacture of cement is completed in a number of basic, sequential steps. 1) the manufacture of cement includes the combination of calcareous and argillaceous raw materials to form a homogenous mixture, 2) the burning of the homogenous mixture in a kiln at temperatures between 1300 and 1500°C (variations based on types of raw materials) to enable a complete chemical combination of silica, lime and alumina to form marble-sized balls called clinkers (Lea, 1970; Williamson, 1972; and Gutcho, 1980), and 3) the grinding of the clinker with the addition of small amounts of gypsum, to make a fine powder. Gypsum, although not a raw material in the kiln feed, is used in Portland cement to regulate the hydration pattern.

Raw materials used in cement production are referred to as primary and secondary materials. They may be available within a range of acceptable raw compositions in a given locality, and several sources may be exploited to arrive at a blend with a composition capable of being burned to an acceptable clinker. Primary raw materials are calcareous, for example, limestone and chalks are a source of CaO. Secondary raw materials are argillaceous, for example clay and shale are the source of SiO_2, Al_2O_3 and Fe_2O_3. These are mixed together in proportions depending upon their own composition, and the required final chemical composition.

Cement companies generally build their cement production plants in close proximity to raw materials to reduce transportation cost. When the primary and secondary raw materials at these sites are deficient in the required chemical constitutes other materials may have to be added in small quantities to offset the deficiency. However, at the same time the corrective ingredients must not contain appreciable amounts of harmful oxides (e.g., MgO or K_2O), which can affect the bonding quality of the cement and result in a shorter lifespan of the concrete. Corrective ingredients could be siliceous, aluminous of ferrugenous materials. Quartz sand is a common ingredient for improving the silica content. Other corrective ingredients include iron pyrite cinders, siliceous loams, diatomaceous earth, and china clays. Industrial waste such as blast-furnace slag from iron and steel industries are also considered as a raw material when easily available. Additives may also be included to control or alter certain properties of cement, depending on its particular usage. Additives are used to accelerate or retard setting, to inhibit shrinkage and to strengthen certain cement products.

The ease of preparation of raw materials for mixing and burning is determined principally by their crushing strength and their abrasive properties. Strength covers a wide range because of differences in both particle size and bonding forces. For burning the raw cement mix, the raw materials are required to be crushed and ground to a certain fineness (325 to 350 m^2/kg surface area for ordinary portland cement; Rye, 1983). The particle-size distribution in ground raw mixes is critical both for the burning potential of the homogenous mixture and clinker comminution. Optimum energy comsumption demands that the raw meal should have adequately homogeneous fineness in the raw mix components because the combining potential of the released oxides of Ca, Si, Al and Fe, depends on the near-uniform fineness of the raw meal components, if it is to occur within a narrow temperature range (Ghosh, 1983).

Only on the basis of a well-homogenized raw mix is it possible to provide a satisfactory cement quality and to maintain smooth kiln operations. An inhomogeneous raw mix would cause difficulities with the operation such as:

a) shorter lifetime of the refractory linings of the kiln,

b) high fuel consumption, and

c) varying clinker comminution

There are instances where minor constituents improve the buring potential of a kiln feed in a substantial manner, thereby reducing energy consumption. The reactivity of materials is often favourably influenced by the presence of iron oxides in the ferrous state. Under identical conditions of fine grinding and rapid cooling, the presence of magnesium silicates ensure even distribution of fine (1 to 5 microns) periclase (MgO) crystals (Ghosh, 1983). Harmful constituents, even in minor amounts, like alkalies, sulphates, magnesium

oxide and phosphorous pentoxide may alter reaction kinetics, phase equilibria relations, clinkering temperature and clinker comminution. Even at levels of less than one percent, heavy metals inhibit the setting of cement. Expansion is caused by the slow hydration of periclase crystals and also by an excessive sulphate level in the cement (Bye, 1983). An increase in silica at the expense of aluminum and ferric oxide content will make the cement harder to clinker but setting time will be easier to control. An increase in aluminum with no change or reduction in ferric oxide content hastens the setting of cement.

Cement Making At the North Star Cement Plant

Raw materials used in cement production by the North Star Cement Company include limestone, shale, silica-rich sand and gypsum. The company's limestone quarry is situated 1 to 1.5 km from the plant, and the shale quarry is on the plant site. Reserves of both are sufficient to sustain well over 50 years of production even allowing for the largest foreseeable demand. Shale comprises 20 percent of the raw mixture used by the North Star Cement Company (Dean and Meyer, 1985) but it has variable geochemical characteristics. To counter this variability, the North Star Cement Company uses a preblended stockpile of shale and silica-rich sand to attain the desired high-silica content. A supply of sand from the present quarry, located near Matthews Brook, has a 3- to 5-year life expectancy at present operation levels. A need for another source of silica is therefore necessary to meet long-term demands of cement production. The plant obtains its gypsum from Flat Bay (approximately 60 km away) and should not experience any problem with supply in the foreseeable future.

Efforts to locate other suitable shale deposits have been unsuccessful (Dean and Meyer, 1985). Silica-rich 'fines' discarded at ERCO's Long Harbour phosphorous plant and high-silica quartzite bedrock in the Corner Brook area are available and chemically suitable. However, high transportation costs in the case of the former, and high quarrying and crushing costs for the latter, make them far from ideal.

Two approaches were discussed with the North Star Cement Company in an attempt to locate suitable silica-rich sands. The first approach was to find a deposit that could serve as a total replacement for shale. The second approach was to locate a suitable deposit that could be used as a fourth component in the cement mix to maintain chemical consistency of the cement. The geochemical constraints for these two approaches are listed in Table 1. Sand used as a total replacement for shale would provide 20 percent of the total mix, whereas sand used as a fourth component in the cement would only constitute 10 percent of the total mix.

A high silica content strengthens the final product. Generally, the higher the silica content the better, but it should not be greater than 80 percent if used as a complete replacement for shale. If the silica content is too high, there could be a problem with crushing the material to the proper fineness. Sands with greater than 80 percent silica would need special machinery for crushing, adding to the cost of overall production. Sand containing up to 95 percent silica is acceptable, if mixed with shale, because the softer shale reduces the effect of the high-silica content. Low levels of other components such as alkalies (<3 percent) and sodium (<1 percent) will ensure long-term strength and stability of the concrete products, in which the cement is used.

Other desired qualities of silica-rich sand deposits are: 1) easy access, 2) uniform grain size and ease of screening (if needed at all), plus low silt-clay content to avoid handling problems and freezing during winter months, 3) uniform geochemical characteristics, and 4) a deposit with reserves of 150,000+ tonnes to meet forseeable demands (i.e., 10 years production at 15,000 tonnes/year).

Previous Work

Preliminary estimates for silica were determined (Bragg, 1985) on selected sand samples collected under the Inventory of Aggregate Resource Program (Kirby *et al.*, 1983). Results from these samples provided data to help determine potential deposits of silica-rich sand in the study area.

Previous sampling and geochemical analyses were done in 1983 on a number of sand quarries in the vicinity of the North Star cement plant (Collins, 1983). One suitable deposit was located near Matthews Brook at Little Rapids, however, this silica-rich sand deposit is nearing depletion.

A Corner Brook shale survey (Dean and Meyer, 1985) was undertaken to locate a deposit with suitable geochemical properties to eliminate the need for a fourth component such as sand, in the blending process. This shale deposit would require an SiO_2/Al_2O_3 ratio of 4:1 or greater, and low levels of MgO, K_2O, Na_2O and less than one percent sulphur. Data from this survey (Table 2) show that none of the deposits examined possess the desired characteristics. The best results were obtained from the North Star shale quarry, which is currently in use.

SILICA-RICH SAND PROJECT

Field Program

The objective of the field program was to locate sand deposits and collect samples for geochemical and particle-size analyses, and to determine their suitability for use in cement production.

Study areas were selected from mapped data compiled under the Inventory of Aggregate Resources Program (Kirby *et al.*, 1983). Where possible, samples were collected at 0.5 m intervals or less from natural exposures such as stream cuts, shorelines and road cuts. From these exposures, samples were obtained that were free of plant debris and topsoil. Where natural exposures were not present, samples were taken from hand-dug pits (approximately 0.8 m in depth) that extended into the C horizon, in order to provide a fresh sample unaffected by weathering. Backhoe test pitting (reaching depths of 3 m) was conducted in selected areas where penetration by pick and shovel was difficult, and in areas where earlier sampling indicated potentially silica-rich deposits. With the aid of 1:50,000 scale black and white air photographs an estimated quantity of material was determined for each deposit where sampling and visual observations were made.

Data Analyses

Preliminary geochemical analyses were conducted at the North Star cement plant in Corner Brook. In areas that indicated encouraging geochemical results, further sampling was undertaken to provide a broader range of analyses. At the end of the field season

detailed geochemical analyses (Table 3) were also conducted at the Department of Mines and Energy laboratory.

Particle-size analyses of deposits that had satisfactory geochemical results are listed in Table 4. Particle-size analyses consisted of field and laboratory sieve analyses. Field sieve analyses were conducted on samples containing +8 mm size material. During field sieve analyses, approximately 10 to 20 kg of material for each test-pit was sampled, weighed and sieved through a bank of four 30 cm diameter sieves (mesh sizes 63 mm, 31.5 mm, 16 mm and 8 mm). A 500 to 1000 gm split of the finer than 8 mm sand/ silt/clay fraction was retained for laboratory sieve analyses.

Laboratory sieve analyses consisted of drying and splitting the sample to 70 to 140 gm, then dry sieving each sample through a bank of eight sieves (8 mm, 4 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm and 0.062 mm).

Cumulative graphs showing total and individual sieve percentages of gravel, sand and silt/clay are available (from the author and/or the Terrain Sciences Section) for all sieved samples.

RESOURCE AREAS

Thirty-eight sand and gravel deposits were sampled between Flat Bay and Deer Lake (Table 3). Based on the geochemical results, the deposits have varying potential for use as a silica-rich sand deposits. Areas that have a low potential are not discussed in this report. Deposits having good or marginal potential are briefly described. These deposits

(located on 1:50,000 scale N.T.S. map sheets 12A/13, 12H/3 and 12H/4) are situated near Humber Village, Matthews Brook, Little Rapids, North Harbour, Dancing Point, Reidville, Rocky Brook, Junction Brook, Pasadena, Hughes Brook and North Brook.

Deposit description includes: a quantitative estimate of the deposit based on aerial-photograph interpretation and field investigation conducted by site observations and backhoe test pitting; geochemical data showing deposit suitability as a mix with shale or replacement for shale in cement production; percentages of gravel, sand and silt-clay and dominant particle-size fraction for each deposit.

Humber Village (NTS 12A/13)

The Humber Village deposit is a large (3,800,000 m³), sand-pebble deposit located on the west bank of the Humber River (Figure 2). Access is gained by crossing a narrow one-lane bridge over the Humber River. The deposit is overlain by farmland, dense tree growth and a residential area. Five aggregate samples collected in this area were taken from roadside drainage ditches (averaging 2 m in depth). Geochemical analyses (Table 5) indicate this deposit would be best used without shale in cement production. Aluminum, iron and alkalie contents are too high, to enable usage of this sand as a mix with shale. Particle-size analyses of five samples (Table 6) show the deposit to be composed of about 35.0 percent gravel, 63.5 percent sand and 1.4 percent silt-clay. The dominant sand fraction occurs between 0.5 and 1.0 mm, and constitutes up 18 percent of the total sieved material (Figure 3). This area is privately owned and the expense of acquiring land may make it too expensive to use this material for cement production.

Matthews Brook (Batstone Quarry - NTS 12A/13)

The North Star Cement Company presently obtains its silica-rich sand from this small deposit (100,000 m³), situated on the south side of the Trans-Canada Highway, approximately 200 m east of Matthews Brook (Figure 2). Samples for geochemical (Table 7) and particle-size analyses (Table 8) were taken from 2 stratigraphic units in an active quarry having an average thickness of approximately seven metres. Results from the analyses of both units show high sand content and low amounts of gravel and silt-clay. The dominant grain size (33 percent) of sieved material occurs between 0.25 and 0.5 mm (Figure 4). The North Star Cement Company has previously conducted extensive geochemical analyses in the deposit (Collins, 1983), which has proven to be good quality, however, because of earlier removal, the quantity of material at this location has been greatly reduced and another source of silica-rich material is needed.

Little Rapids (NTS 12A/13)

This deposit contains approximately 50,000 m³ of material. It is the site of an abandoned quarry situated between the railway track and the Trans-Canada Highway in Little Rapids (Figure 2). It is partly overgrown by low bushes and trees. Houses located in the vicinity may pose some restriction to excavation. Geochemical characteristics (Table 9) of sampled material indicate this deposit is suitable as a replacement for shale but unsuitable as a mix with shale due to high aluminum and alkali contents. Screening will be required to remove the gravel (Table 10). Particle-size analysis show material in the deposit to be generally less than 16 mm. The dominant grain size occurs between 0.25 and 0.5 mm making up 22 percent of the total sieved material (Figure 5). The location, small size

and gravel content of this deposit may make it unfeasable for extracting sand for use in cement production.

Northern Harbour - Grand Lake (NTS 12H/3)

The North Harbour - Grand Lake deposit is a small deposit (6000 m^3), situated approximately 13 km south of Pasadena, near the end of a gravel-based logging road (Figure 6). One sample was collected from an approximate 12-m-high stream exposure. Geochemical analyses indicate that this material is suitable for use in cement production (Table 11), but only when used as a total replacement for shale. This is because the aluminum and iron content are too high to make use of this deposit as a mix with shale. Particle-size analyses indicate that this deposit contains a coarse gravel fraction (Table 12) with the dominant grain size occurring in the +63 mm sieve, and forming 14 percent of sieved material (Figure 7). Large boulder material (>30-m diameter) was observed along the exposure. The coarse texture of this deposit will result in high wastage if screening is undertaken. Screening, plus the small size of this deposit and it's distance from Corner Brook, greatly reduces its potential for use in cement making.

Dancing Point (NTS 12A/13)

This deposit contains approximately 400,000 m^3 of material. It is situated on the north side of the Humber River near its exit into Humber Arm (Figure 8), and is the nearest silica-rich sand deposit to the North Star cement plant. Two stratigraphic units of material, approximately 6 m each in thickness, are exposed in an abandoned quarry in this deposit. Geochemical analyses of samples taken from these 2 units are similar (Table 13)

and indicate this material is adequate for use in cement production as an alternative to shale. Aluminum and iron content are slightly above the recommended levels, making this material unsuitable for use with shale. Samples collected from backhoe dug pits (Kirby, 1982) and quarry exposures indicated this deposit is composed of dominantly fine grain sand with lower gravel and silt-clay content. Particle-size distribution varies considerably between sample sites. Gravel content occurs in a range from 0.5 to 89.6 percent; sand from 10.1 to 95.7 percent and silt-clay from 0.5 to 89.6 percent (Table 14). The dominant particle size occurs between 0.5 and 0.25 mm, forming approximately 35 percent of sieved material (Figure 9).

Sample data indicate potential sites within this deposit, however grain-size analyses from material taken in backhoe due pits is limited to the top 3 m and does not indicate extent and depth of silt-clay units, which could greatly reduce deposit potential as a source for use in cement production.

Reidville (NTS 12H/3)

The Reidville deposit is located approximately 2 km northeast of Reidville along the north side of the upper Humber River (Figure 10). This large deposit (3,900,000 m^3) is overlain by dense tree growth and abandoned farmland.

Sampled material was collected from a 3.2-m road cut, and from 2 backhoe dug pits located approximately 400 m northwest of the Humber River, which revealed only 0.9 m and 0.4 m of sand over an undetermined thickness of clay. Providing K_2O values do not reach higher proportions in future sampling, geochemical analysis (Table 15) indicate this

deposit may have potential for replacing the shale component in cement production. Iron and Na_2O are too high to use material from this location as a mix with the shale component. Particle-size analyses indicate sand-size fraction dominates (95.13 percent), with only 4.3 percent gravel and 0.6 percent silt-clay (Table 16). No boulder or cobble material was observed in this deposit. Material ranges from 0.062 to 8 mm with the most dominant (44 percent) to occur between 0.25 and 0.5 mm (Figure 11) in sieved material.

Due to geochemical variations and the presence of an extensive clay layer beneath the sand, this deposit may be deamed unsatisfactory for use in production of cement.

Rocky Brook (NTS 12H/3)

The Rocky Brook deposit contains approximately 7,000,000 m^3 of material. It is situated near the intersection of the Reidville highway and Rocky Brook (Figure 10). The geochemistry of sampled material (Table 17) is similar to that of the Reidville deposit although it contains less K_2O, making it more favourable for replacing the shale component in cement production. The deposit consists predominently of sand with minor coarser material. Grain-size analyses of two samples gave an average content of 84 percent gravel, 79.1 percent sand, and 12.4 percent silt-clay (Table 18). Particle sizes between 0.125 and 0.25 mm appear to be most dominant, forming 29 percent of sieved material (Figure 12). Pebbles appear to be concentrated in the top 3m of the deposit with high concentration of sand and silt materials at lower depths. Wide variations occur in the grain-size distribution of these two samples. Gravel ranges from 0.2 to 16.7 percent and silt-clay from 1.0 to 24.0 percent. A 64 percent difference is shown in the sand content. From these results it is clear

that a detailed study is required in this area to determine its potential for use in cement making.

Junction Brook (NTS 12H/3)

Junction Brook intersects the Trans-Canada Highway approximately 10 km northeast of Deer Lake (Figure 10). This is an extensive deposit, which has been divided into three zones based on geochemistry (Table 19) and particle-size distribution (Table 20).

Zone 1 constitutes the eastern section of the deposit between Junction Brook and the Trans-Canada Highway and contains approximately 3,000,000 m^3 of material. An asphalt plant and a Newfoundland Department of Transportation depot are presently situated within this area. Sampled material show acceptable geochemical properties for this deposit although the alkali content is to high (>2 percent) for this material to be used in combination with shale in cement production. Zone 1 has an average gravel content of 24 percent, sand 74 percent and silt-clay 1 percent. Material between 0.5 mm to 1 mm is dominant, forming 24 percent of the sieved material (Figure 13). Particle-size analyses of seven samples show wide variations from one sample site to another. Some samples show a mixture of fine and coarse material whereas others show a dominant medium to fine grade of sand. Screening or crushing will be required to remove the gravel content in this zone. The increases cost of excavating plus alkali content reduce its potential for use in cement production.

Zone 2 is located on the north side of Junction Brook near its confluence with the upper Humber River and contains approximately 2,500,000 m^3 of material. Geochemical

results show an average silica content of 79.45 percent, ranging from 74.35 to 82.90 percent in analyses of four samples. Other components fit within the geochemical range, possibly allowing this material to be used in cement production.

This area is dominantly composed of sand (85.26 percent). Field sieving was required on one of eight samples collected, indicating that most material is smaller than 8 mm. Grain-size analyses show the dominant particle size to occur between 1.25 and 0.5 mm forming 24 percent of sieved material (Figure 14). Samples were taken from backhoe pits and roadside exposures.

Providing the silica content is not to great, Zone 2 could be the most promising areas for a silica-rich sand deposit for use in cement production. It shows the best geochemical results and has the highest concentration of sand-size material.

Zone 3 is located on the south side of Junction Brook, approximately 1 km west of the Deer Lake municipal dump. It is the smallest of the three zones at Junction Brook, containing 400,000 m^3 of material. Geochemical results are similar to those for Zone 2, and for this reason, the high silica content may cause concern in this zone also. Although the gravel content is not high (18.77 percent), it may be a negative factor in developng this zone over zone 2, which is much larger and contains less coarse material. An average sand content of 80.3 percent and 1.0 percent silt-clay was determined from sieve analyses of eight samples. The dominant grain size occurs between 0.25 and 0.5 mm, forming 30 percent of sieved material (Figure 15).

Pasadena (NTS 12H/4)

The Pasadena deposit, containing approximatley 500,000 m^3 of material, is located on the east side of Grand Lake road, south of Pasadena (Figure 16). Only one sample was collected in this deposit, from a small borrow pit (approximately 5-m long by 5-m wide) having a maximun exposure of 1 m. Geochemical results (Table 21) indicate this deposit is suitable as a mix with shale, and possibly as a total replacement for shale, providing a future sampling does not show higher levels of aluminum. Particle-size analysis (Table 22) show a gravel content of 34.3 percent. The dominant particle-size material occur between 1.0 and 2.0 mm, forming 23 percent of sieved material (Figure 17). Further sampling, backhoe test pitting and analyses will be required to determine the extent and potential of this deposit.

Hughes Brook (NTS 12H/4)

Hughes Brook intersects the Northshore highway approximately 7 km north of Corner Brook. There are several sand deposits located along the Hughes Brook valley on the north side of the Northshore highway (Figure 18). These deposits are overlain by dense tree growth, cut-overs and farmland. These deposits are variable in size, geochemistry (Table 23) and textures (Table 24).

Deposit 1, situated along the valley floor is the largest (1,000,000 m^3) in the Hughes Brook area. It is generally flat, tree covered, and is used as agriculture land in the south. Samples were collected from 2 backhoe pits, dug approximately 250 m west of Hughes Brook (depth of 3.3 m) and from 2 stream cuts with exposures of 3.5 m and 4 m.

Backhoe pits showed a sand thickness of 0.6 and 1.9 m, overlying an undetermined thickness of silt and fine sand. Stream cuts revealed a pebble gravel layer ranging in thickness from 0.2 to 1.3 m, overlying the sand layer.

Geochemical analyses of three samples indicate this deposit would be best used as a replacement for the shale component. Variable silica concentrations (9 to 13 percent) and high Na_2O (2.22 percent) make it unsuitable as a mix with shale. Grain-size analyses show an average 23.3 percent gravel 70.3 percent sand and 6.4 percent silt-clay. The dominant particle-size occurrs between 0.125 and 0.25 mm, forming 19 percent of sieved material (Figure 19). Particle-size analysis do not include material from the lower sand-silt layer observed in backhoe test-pits.

Deposit 2 is situated approximately 200 m south of deposit one. It is much smaller (100,000 m^3) in size but does contain favourable geochemical characteristics indicating it to be useful as a replacement for shale. High Na_2O concentrations make it unsuitable for use as a mix with shale. Particle-size analyses show it to be composed of sand and silt material and the dominant particle-size occurring between 0.125 and 0.25 mm, forming 45 percent of the deposit (Figure 20). High silt-clay content and its small size will likely make it unsuitable for use in cement production.

Deposit 3 is located along a road cut near a steep rock face. It has suitable geochemical charcteristics for use as a replacement for shale but is small in size (1.350 m^3) and contains a high silt-clay content (63.3 percent). The dominant particle-size occurs below the smallest sieve size (0.062 mm) in the pan fraction, forming 53 percent of the deposit (Figure 21).

Deposit 4 is another small deposit (150,000 m³) at Hughes Brook but contains less silt-clay content than deposits 1, 2, and 3 (Figure 22). Scattered boulders ranging from 0.2 to 0.4 m in diameter are distributed throughout this deposit. Deposit 4 consists of 2 stratigraphic units, approximately 3.5 m each in thickness. Unit one shows poor geochemical results and has a high gravel content (38.1 percent). The dominant particle-size in unit one occurs in four sieve fractions between 1 mm and 16 mm, each containing approximately 20 percent of the deposit making up 58 percent of this unit. Unit 2 of Deposit 4 has more favourable geochemical results and consist of finer grain-size material with low gravel content (1.5 percent), excluding scattered boulders. The approximate 16 percent silt-clay maybe a negative factor in this unit. The dominant particle-size occurs between 0.25 and 0.125 mm making up 44 percent of this unit. Poor geochemical characteristics in Unit 1 make this deposit unsuitable for use in cement production.

North Brook (NTS 12H/4)

The North Brook deposit is situated along a gravel-based logging road on the north side of Deer Lake approximately 6 km southwest of Nicholsville (Figure 23). This is a substantial deposit (19,000,000 m³), with a estimated deposit thickness up to 12 m, and is overlain by moderate to dense forest growth. Samples were collected from 6-m exposures visible along most of the shoreline section. This deposit maybe less suitable than others due to high values of MgO (Table 25) in four of the seven samples collected. Composition, determined by particle-size analyses indicate that this deposit is composed of predominantly sand (80.11 percent) plus pebble material and minor silt/clay concentrations (Table 26). The dominant particle-size occurs between 0.25 and 0.5 mm forming approximately 23 percent of the total deposit (Figure 24). Due to variable geochemical characteristics, and large size

of this deposit it will be necessary to conduct a more detailed sampling program to determine potential sites for mining silica-rich sand for use in making cement.

Other Deposits

In addition to deposits previously discussed, several others were sampled but show less than adequate potential for use in making cement. Many deposits have low silica and aluminun ratios and/or high alkali or magnesium content, which reduces their potential for use as a corrective ingredient in the production of cement.

Other deposits showing marginal geochemical potential may have some value if blended with higher quality materials. One of these deposits is located near the Deer Lake airport. In this deposit, the percentage of K_2O would have to be reduced by blending with another deposit with lower values of K_2O such as Deposits 1 to 4 at Hughes Brook. Blending may also be a good practice to reduce the precentage of high silt-clay content in some deposits.

TRUCKING DISTANCE

Transport distance from the deposit site to the production plant will likely be an influencing factor if any deposit is considered useful in cement production. The distance of potential deposits from the North Star cement plant ranges between 5.2 and 62 km (Table 27).

Transport rates are generally established on a 'ton mile' basis, where the rate structure provides for marginally decreasing unit cost, per ton mile for marginal increases in distance hauled, up to a maximum distance of 50 miles. Beyond 50 miles the rate charged is usually costant and is negotiated between shipper and carrier (Carter 1981). Table 28, although dated gives some insight on how this system operates.

Deposits located along gravel-base roads, where driving conditions are poor and speeds greatly reduced, such as the North Harbour deposit, may be less likely to be chosen over more easily accessible deposits located at greater distances from the cement production plant, such as deposits at Junction Brook.

SUMMARY

Thirty-eight sand and gravel deposits in western Newfoundland were sampled to test their potential for use in cement production. Few of these deposits show suitable or marginally acceptable geochemical results. Some have a coarse gravel content and thus require screening and others have high silt-clay content, which may result in freezing during winter months. Transportation may also be a negative factor especially for those east of Deer Lake. Private-land ownership may result in sterilization of some deposits and others may not be utilized because of their proximity to houses or insufficient quantities or expensive mining cost (crushing and screening). Deposits that show marginal geochemical suitability, but only have few analyses, will require further investigation to determine quality and/or quantity.

Despite the above limitations, there are a number of potential deposits that appear to meet the requirements of the North Star Cement Company. These would include the following:

1) The Dancing Point deposit has suitable geochemical characteristics, but will require further sampling and analysis to determine the extent of silt-clay units. It's proximity (1.5 km) to the North Star cement plant will also make this deposit favourable for development if grain-size distribution and land availability is not a problem.

2) Deposit 1 at Hughes Brook has suitable geochemical characteristics but will also require further sampling and analysis to determine the extent of silt-clay units.

3) The deposit that shows the greatest potential, although located at a greater distance from Corner Brook than either Dancing Point or Hughes Brook deposits, is Zone 2 at Junction Brook. Zones 1 and 3 are also within the allowable geochemical range. This deposit has a considerable quantity of material (zones 1, 2 and 3 have as estimated combined volume of 6,000,000 m^3) and can supply material for many years at maximum production capacity.

In reviewing Tables 3 and 4, it is apparent that many deposits sampled vary considerably in their geochemical characteristics and texture. Some deposits fall within the recommended range for geochemical composition, whereas others many fall slightly outside this range and others show no suitability at all. Besides the high-potential deposits noted above, it may also be possible to blend some of the unfavourable deposits so that negative

elements in one may be counter-balanced by the positive elements of the other. Blending of sand deposits will result in extra time and workload, but if access to high-quality deposits is denied, the increased cost of blending may be acceptable.

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Table 1. Geochemical constraints for sand used in cement production

Approaches	Percent sand of total mix	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	Alkalies %	SO_3 %
Total replacement for shale	20	60-80	9-13	0-8	0-10	<2	<3	<1
Fourth component in cement mix	10	70-95	5-10	0-4	0-4	<2	<2	<0.25

Table 2. Results of Corner Brook shale survey. Compiled by Dean and Meyer (1985)

FORMATION	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	SO_3 %	MgO %	K_2O %	TiO_2 %	Number of Samples Averaged	SiO_2: Al_2O_3:
Summerside	52.3	17.7	7.0	0.7	0.1	3.5	3.3	0.8	4	2.80:1
Irishtown	49.8	20.3	6.9	1.5	0.3	3.4	2.8	0.8	22	2.45:1
North Star shale	57.0	15.0	5.5	-	1.3	3.8	2.8	-	average from North Star	3.80:1
(Black Cove ?) Green shale and sandstone	52.7	13.9	6.3	4.3	0.1	5.1	2.3	0.6	26	3.79:1
Rocky Brook	38.9	10.3	4.5	9.7	0.3	10.4	0.5	2.1	7	3.77:1

Table 3. Averaged geochemical analyses of samples collected in silica sand deposits in western Newfoundland

Deposit	NTS	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	SO	L.O.I.
Humber Village	12A/13	74.3	11.55	3.55	1.35	1.06	2.66	2.12	0.48	0.16	0.07	0.01	2.67
Matthews Brook	12A/13	78.65	9.54	2.66	0.03	0.99	2.51	1.78	0.47	0.08	0.10	0.04	1.87
Little Rapids	12A/13	76.90	10.48	2.96	1.15	0.83	2.49	2.11	0.44	0.09	0.10	0.03	2.24
North Harbour - Grand Lake	12A/13	74.55	11.31	4.81	1.30	0.80	2.28	1.93	0.68	0.11	0.13	0.03	1.97
Trout Creek	12A/13	79.50	8.61	3.60	1.10	0.53	1.88	1.51	0.54	0.10	0.10	-	2.04
Summerside	12A/13	57.80	7.06	2.97	4.13	11.75	1.33	1.31	0.39	0.08	0.08	0.07	13.22
Dancing Point	12A/13	73.05	10.88	4.21	1.17	2.37	2.36	1.84	0.70	0.10	0.11	-	3.10
St. Teresa	12B/07	66.00	16.70	3.31	1.41	4.49	3.75	1.27	0.49	0.06	0.09	-	2.35
Muddy Hole	12B/07	62.73	18.83	3.79	1.68	4.94	4.28	1.15	0.53	0.06	0.09	-	1.81
Little Barachois	12B/08	57.67	16.89	6.86	3.95	6.60	3.55	1.28	0.92	0.12	0.21	0.05	1.75
Journois Brook	12B/08	65.42	17.29	3.45	1.75	4.46	3.97	1.10	0.39	0.06	0.08	-	1.87
Flat Bay Brook	12B/08	64.78	17.28	4.04	1.79	4.46	3.84	1.19	0.55	0.08	0.09	-	2.22
Southwest Brook	12B/08	60.21	16.24	6.97	3.3	16.62	2.96	1.55	0.75	0.11	0.21	0.04	1.49
Bottom Brook	12B/09	64.55	16.13	5.26	2.38	4.66	3.41	1.68	0.60	0.10	0.11	0.06	1.20
Moose Pond Road - Harrys River	12B/09	61.29	13.94	5.92	3.76	6.43	3.14	1.76	0.74	0.11	0.13	-	4.74
Crescent Pond Road	12B/09	63.0	14.07	6.62	3.58	4.35	3.33	1.74	0.78	0.13	0.12	0.04	2.23
Grand Lake	12B/09	61.53	14.13	5.79	3.28	5.10	3.26	1.70	0.80	0.13	0.12	0.04	2.99
Trout Brook (East)	12B/09	73.47	13.80	1.89	0.28	1.15	4.12	4.35	0.27	0.04	0.05	0.04	2.20
Trout Brook (Central)	12B/09	62.10	14.64	7.39	3.51	4.02	3.45	1.56	0.92	0.13	0.14	0.05	2.07
Trout Brook (West)	12B/09	61.45	14.55	7.43	3.75	4.91	3.30	1.58	0.87	0.14	0.13	0.05	2.43
Noels Pond	12B/10	59.82	13.87	6.55	3.49	18.67	3.08	1.80	0.77	0.12	0.12	0.04	4.56
Cold Brook	12B/10	58.98	11.08	4.43	2.86	9.95	2.58	1.91	0.58	0.10	0.09	0.05	8.16
Cooks Cove	12B/16	57.80	7.06	2.97	4.13	11.75	1.33	1.31	0.39	0.08	0.08	0.07	13.22
Blow Me Down Brook	12G/01	47.03	4.39	8.11	26.44	1.81	0.76	0.39	0.22	12.50	0.06	0.04	10.51
Nicholsville	12H/03	65.29	16.45	3.51	1.86	4.15	3.58	1.69	0.46	0.06	0.10	-	2.70
Rocky Brook	12H/03	70.60	10.38	3.53	1.74	3.04	2.11	2.58	0.59	0.08	0.08	-	4.82
Reidville	12H/03	74.00	10.75	2.59	1.78	0.77	7.06	3.23	0.29	0.08	0.08	-	3.46
Junction Brook Zone 1	12H/03	78.08	10.33	2.26	0.77	0.81	2.92	2.59	0.25	0.06	0.09	-	1.41
Zone 2	12H/03	79.45	8.93	2.51	1.02	1.03	2.28	2.27	0.36	0.07	0.07	-	2.14
Zone 3	12H/03	81.10	8.49	2.38	0.72	0.76	2.26	2.20	0.37	0.07	0.06	-	1.43
Deer Lake Airport	12H/03	72.60	11.00	3.52	2.01	0.92	1.92	3.13	0.46	0.07	0.09	0.04	3.72
Little Harbour	12H/03	67.85	13.95	6.05	1.63	0.65	2.14	2.58	0.64	0.12	0.16	-	3.18
North side of Deer Lake	12H/04	71.46	10.89	3.51	2.43	1.86	1.81	2.51	0.42	0.08	0.06	0.03	4.76

Table 3. Continued

Deposit	NTS	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	SO_3	L.O.I.
Pynns Brook	12H/04	75.83	10.00	3.56	2.12	0.74	2.45	1.70	0.41	0.10	0.09	-	2.60
Pasadena	12H/04	80.40	8.77	2.35	0.95	0.41	1.98	1.72	0.38	0.08	0.09	0.03	2.30
Hughes Brook (North) Deposit 1	12H/04	74.22	10.52	3.42	1.30	2.10	2.22	1.92	0.64	0.09	0.13	0.08	2.53
Deposit 2	12H/04	78.30	9.90	3.04	0.91	0.69	2.35	1.89	0.55	0.09	0.12	0.03	1.52
Deposit 3	12H/04	72.30	9.67	3.09	0.91	4.32	2.27	1.74	0.53	0.08	0.14	0.03	4.37
Deposit 4	12H/04	61.56	8.36	2.98	2.82	10.28	1.75	1.51	0.38	0.09	0.06	0.03	10.92
Deposit 5	12H/04	41.35	5.59	2.37	7.58	17.87	1.05	1.22	0.32	0.07	0.06	0.07	22.08

Note: Percentages are based on a compilation of individual samples from each deposit. In many areas only one sample was collected. SO_3 analyses were provided by the North Star Cement Company. The dash (-) indicates there are no SO_3 analyses.

Table 4. Aggregate summary of silica-rich sand deposits in western Newfoundland

Deposit	Cubic metres	Number of samples collected	Percent gravel (+5 mm)	Percent sand (+0.074 mm to -5 mm)	Percent silt - clay (-0.074 mm)
Humber Village	3,800,000	5	35.0	63.5	1.4
Matthews Brook	100,000	2	7.1	89.7	3.1
Little Rapids	50,000	1	26.7	72.2	1.1
North Harbour - Grand Lake	6,000	1	49.6	49.5	0.9
Dancing Point	400,000	13	17.8	68.1	14.1
Reidville	3,900,000	3	4.3	95.1	0.6
Rocky Brook	12,240,000	2	8.4	79.1	12.4
Junction Brook Zone 1	3,000,000	7	24.0	75.0	1.0
Zone 2	2,500,000	8	11.6	85.3	3.1
Zone 3	400,000	5	18.7	80.3	1.0
Pasadena	500,000	1	34.3	65.3	0.4
Hughes Brook Deposit 1	1,000,000	4	23.3	70.3	6.4
Deposit 2	100,000	1	0	80.4	19.6
Deposit 3	1,350	1	0	36.7	63.3
Deposit 4	150,000	4	20.5	71.1	8.4
North Brook	19,000,000	7	18.5	80.0	1.5

Note: Estimated quantities given in table are based on aerial photograph interpretation and field investigation conducted by site obeervation and backhoe test pitting. Percentages are based on a compilation of individual samples and do not take into account extent and depth of deposits at any one locality.

Table 5. Geochemical results of sampled material at Humber Village

Sample Number	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5	L.O.I.	SiO_2:Al_2O_3
863048	75.45	11.08	3.09	1.36	0.77	2.49	2.40	0.42	0.10	0.11	2.56	6.81:1
863049	77.10	10.49	2.42	1.07	0.82	2.72	2.12	0.38	0.05	0.11	2.02	7.35:1
863176	71.25	12.69	4.40	1.61	1.72	2.82	2.04	0.61	0.46	0.07	2.41	5.61:1
863177	70.60	13.21	4.21	1.84	1.28	2.93	2.19	0.55	0.16	0.06	3.03	5.34:1
863178	77.10	10.29	2.62	0.87	0.73	2.32	1.84	0.43	0.04	0.01	3.32	7.49:1

Table 6. Particle-size analyses of sampled material at Humber Village.

Sample Number	Gravel %	Sand %	Silt-Clay %
863048	8.4	90.7	0.8
863049	5.1	94.8	0.1
863176	71.0	28.7	0.2
863177	70.3	29.0	0.6
863178	20.4	74.5	5.1

Table 7. Geochemical results of sampled material near Matthews Brook

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
(Unit 1) 863051	76.60	10.15	3.13	1.23	1.18	2.56	1.83	0.50	0.08	0.11	2.16	7.55:1
(Unit 2) 863052	80.70	8.92	2.19	0.83	0.80	2.45	1.73	0.43	0.08	0.09	1.57	9.05:1

Table 8. Particle-size analyses of sampled material near Matthews Brook

Sample Number	Gravel %	Sand %	Silt-Clay %
(Unit 1) 863051	14.3	85.0	0.8
(Unit 2) 863052	0.0	94.5	5.5

Table 9. Geochemical results of sampled material at Little Rapids

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
863050	76.90	10.48	2.96	1.15	0.83	2.49	2.11	0.44	0.09	0.10	2.24	7.34:1

Table 10. Grain-size analyses of sampled material at Little Rapids

Sample Number	Gravel %	Sand %	Silt-Clay %
863050	26.7	72.2	1.1
750153	18.8	80.2	1.0

Table 11. Geochemical results of sampled material near North Harbour

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
863053	74.55	11.31	4.81	1.30	0.08	2.28	1.93	0.68	0.11	0.13	1.97	6.59:1

Table 12. Particle-size analyses of sampled material near North Harbour.

Sample Number	Gravel %	Sand %	Silt-Clay %
863053	49.6	49.5	0.9

Table 13. Geochemical results of sampled material collected near Dancing Point

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
(Unit 1) 863090	71.75	11.22	4.40	1.19	2.41	2.32	1.87	0.71	1.10	0.12	3.28	6.39:1
(Unit 2) 863091	74.35	10.54	4.01	1.15	2.32	2.39	1.80	0.69	0.10	0.09	2.29	7.05:1

Table 14. Particle-size analyses of sampled material near Dancing Point. (1982 sample data collected by F.T. Kirby).

Sample Number	Gravel %	Sand %	Silt-Clay %
863090	29.3	70.2	0.5
863091	4.8	87.7	7.5
821215	7.7	76.4	16.0
821216	49.2	49.2	1.6
821217	27.5	70.5	2.0
821218	2.4	95.7	1.9
821219	34.4	64.7	1.0
821220	17.3	80.4	2.3
821227	55.52	41.46	2.92
821228	0	92.6	7.4
821229	0	58.1	41.9
821230	0.3	10.1	89.6
821231	3.3	88.5	8.2

Table 15. Geochemical results of sampled material near Reidville

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
863060	71.55	11.28	4.35	2.14	1.01	1.94	2.95	0.75	0.09	0.13	3.46	6.34:1
863198	74.00	10.75	2.58	1.78	0.77	2.06	3.23	0.29	0.08	0.08	3.46	6.88:1

Table 16. Particle-size analyses of sampled material near Reidville

Sample Number	Gravel %	Sand %	Silt-Clay %
863060	0.2	99.5	0.3
863198	3.6	95.6	0.8
783989	9.1	90.3	0.7

Table 17. Geochemical results of sampled material near Rocky Brook

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
863061	70.60	10.38	3.53	1.74	3.04	2.11	2.58	0.59	0.08	0.08	4.82	6.80:1

Table 18. Particle-size analyses of sampled material near Rocky Brook.

Sample Number	Gravel %	Sand %	Silt-Clay %
863061	0.2	75.9	23.9
793983	16.7	82.3	1.0

Table 19. Geochemical results of sampled material near Junction Brook

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
Zone 1												
863082	78.75	10.13	2.00	0.77	0.71	2.76	2.59	0.25	0.05	0.09	1.53	7.11:1
863083	77.40	10.42	2.51	0.77	0.91	3.08	2.58	0.25	0.07	0.08	1.28	7.43:1
Zone 2												
863084	74.35	10.21	2.80	1.69	1.93	2.55	2.50	0.29	0.07	0.08	3.54	7.28:1
863085	78.25	9.54	2.66	1.30	0.69	2.12	2.43	0.32	0.06	0.07	2.61	8.20:1
863086	82.30	8.51	1.95	0.74	0.61	2.23	2.23	0.24	0.06	0.05	1.62	9.67:1
863087	82.90	7.47	2.61	0.35	0.88	2.21	1.93	0.58	0.08	0.08	0.78	11.1:1
Zone 3												
863084	79.60	9.11	2.53	0.87	0.73	2.33	2.34	0.29	0.07	0.06	1.75	8.74:1
863089	82.60	7.87	2.22	0.56	0.78	2.18	2.06	0.45	0.06	0.06	1.10	10.50:1

Table 20. Particle-size analyses of sampled material near Junction Brook.

Sample Number	Gravel %	Sand %	Silt-Clay %
Zone 1			
78-3937	7.4	91.1	1.5
78-3938	19.1	80.8	0.1
78-3939	0.0	96.5	3.5
78-3940	54.6	45.1	0.4
78-3941	58.8	41.0	0.2
86-3082	20.5	78.4	1.1
86-3083	7.1	92.9	0.0
Zone 2			
863084	50.7	49.3	0.1
863085	14.9	83.8	1.3
863086	12.1	85.2	2.7
863087	0.0	83.8	16.2
863194	6.3	93.2	0.5
863195	0.2	97.1	2.7
863196	1.9	96.6	1.5
863197	6.7	93.1	0.2
Zone 3			
842120	2.1	97.8	0.1
842121	48.1	50.3	1.7
842122	0.0	99.0	1.0
863088	43.4	55.3	1.3
863089	0.0	98.9	1.1

Table 21. Geochemical results of sampled material near Pasadena

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
863055	80.40	7.77	2.35	0.95	0.41	1.98	1.72	0.38	0.08	0.09	2.30	10.35:1

Table 22. Particle-size analyses of sampled material near Pasadena.

Sample Number	Gravel %	Sand %	Silt-Clay %
863055	34.3	65.3	0.4

Table 23. Geochemical results of sampled material near Hughes Brook

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I %	SiO_2:Al_2O_3
Deposit 1												
863188	78.65	9.36	3.01	1.00	0.83	2.12	1.76	0.59	0.09	0.06	1.49	8.40:1
863190	77.15	9.25	2.62	0.99	2.01	2.43	1.62	0.57	0.09	0.13	2.09	8.34:1
863191	66.85	12.95	4.66	1.91	3.45	2.10	2.37	0.75	0.10	0.19	4.02	5.16:1
Deposit 2												
863002	78.3	9.9	3.04	0.91	0.69	2.35	1.89	0.55	0.09	0.12	1.52	7.91:1
Deposit 3												
863003	72.30	9.67	3.09	0.91	4.32	2.27	1.75	0.53	0.08	0.14	4.37	7.48:1
Deposit 4												
(Unit 1)												
863000	50.20	7.56	3.12	4.00	16.24	1.27	1.35	0.29	0.11	0.07	6.52	6.64:1
863126	54.15	8.88	3.60	4.34	12.53	1.68	1.47	0.36	0.10	0.03	13.10	6.10:1
(Unit 2)												
863001	73.15	8.96	2.61	1.18	4.64	2.19	1.69	0.44	0.07	0.09	6.42	8.16:1
863127	68.14	8.05	2.58	1.76	7.69	1.85	1.54	0.43	0.07	0.03	7.63	8.46:1

Table 24. Particle-size analyses of sampled material near Hughes Brook

Sample Number	Gravel %	Sand %	Silt-Clay %
Deposit 1			
863188	0.9	94.7	4.4
863189	24.9	69.6	5.5
863190	15.4	70.7	13.9
863192	52.0	46.0	2.0
Deposit 2			
863002	0.0	80.4	19.6
Deposit 3			
863003	0.0	36.7	63.3
Deposit 4			
(Unit 1)			
863000	38.1	61.1	0.8
863126	43.7	55.7	0.4
(Unit 2)			
863001	0.0	81.3	18.7
863127	0.3	86.2	13.6

Table 25. Geochemical results of sampled material near North Brook

Sample Number	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	MnO %	P_2O_5 %	L.O.I. %	SiO_2:Al_2O_3
863008	73.90	11.18	3.59	2.13	0.66	1.94	2.75	0.39	0.10	0.11	3.69	6.61:1
863182	69.40	13.92	4.47	2.16	0.71	2.25	2.63	0.50	0.12	0.07	3.95	4.99:1
863183	75.30	0.72	3.41	1.73	0.69	1.85	2.53	0.42	0.06	0.05	3.21	7.02:1
863184	73.30	11.02	3.39	1.77	1.29	1.89	2.49	0.37	0.06	0.05	3.38	6.65:1
863185	68.65	11.15	3.75	2.88	2.81	1.93	2.39	0.46	0.06	0.06	5.59	6.16:1
863186	62.85	8.95	2.81	4.47	6.22	1.50	2.15	0.38	0.07	0.06	9.97	7.02:1
863187	76.80	9.26	3.17	1.87	0.61	1.51	2.61	0.41	0.08	0.03	3.51	8.29:1

Table 26. Particle-size analyses of sampled material near North Brook

Sample Number	Gravel %	Sand %	Silt-Clay %
863008	16.9	81.3	1.8
863182	32.4	67.4	0.2
863183	3.9	92.1	4.0
863184	32.2	66.5	1.2
863185	29.0	69.5	1.5
863186	13.3	86.0	0.7
863187	1.4	98.0	0.6

Table 28. Distace of silica-rich sand deposits from the North Star Cement plant, Corner Brook

DEPOSITS	Distance (km) from North Star Cement Plant	DEPOSITS	Distance (km) North Star Plant
Dancing Point	5.2	Pasadean	26
Hughes Brook (Deposit 3)	13.1	North Harbour -Grand Lake	39
Hughes Brook (Deposit 4)	13.8	Rocky Brook	58
Hughes Brook (Deposit 2)	14.5	Junction Brook (Zone 1)	59
Hughes Brook (Deposit 1)	14.8	Junction Brook (Zone 3)	61
Little Rapids	17.2	North Brook	61
Matthews Brook	18.3	Junction Brook (Zone 2)	62
Humber Village	18.7	Reidville	62

Table 27. Total and average cost of truck transport of sand, gravel and crushed materials for various distances in Newfoundland, 1977. (Compiled by Carter, 1981)

Distance Hauled (In Miles)	Total Cost (Per Ton)	Average Cost (Per Ton Mile)
1	$0.38	$0.38
5	0.79	0.16
10	1.32	0.13
20	2.36	0.12
30	3.04	0.10
40	3.56	0.09
50	4.08	0.08
60	5.00	0.08
75	6.38	0.09
100	8.68	0.09
125	10.28	0.09
150	13.28	0.09
200	17.88	0.09

Figure 1. *General location map showing silica-rich sand deposits sampled in western Newfoundland.*

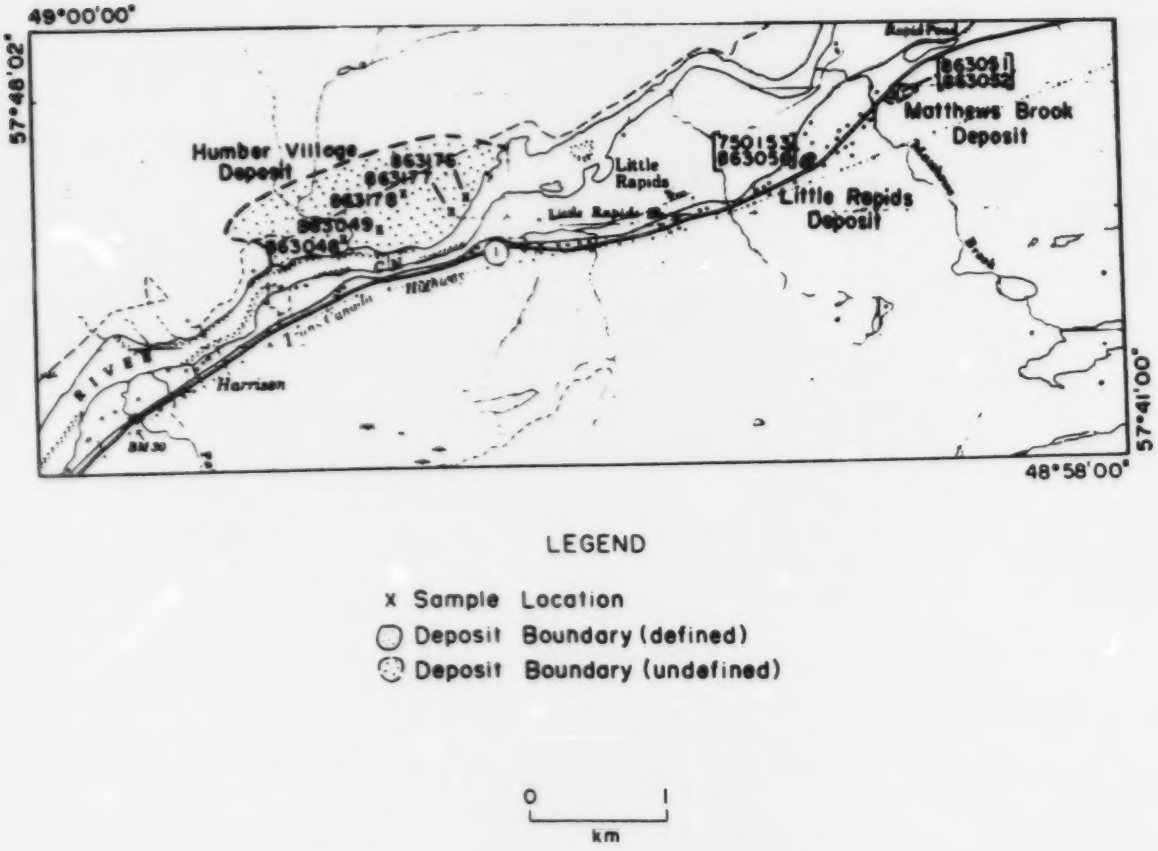

Figure 2. *Silica-rich sand deposits at Humber Village, Little Rapids and Matthews Brook.*

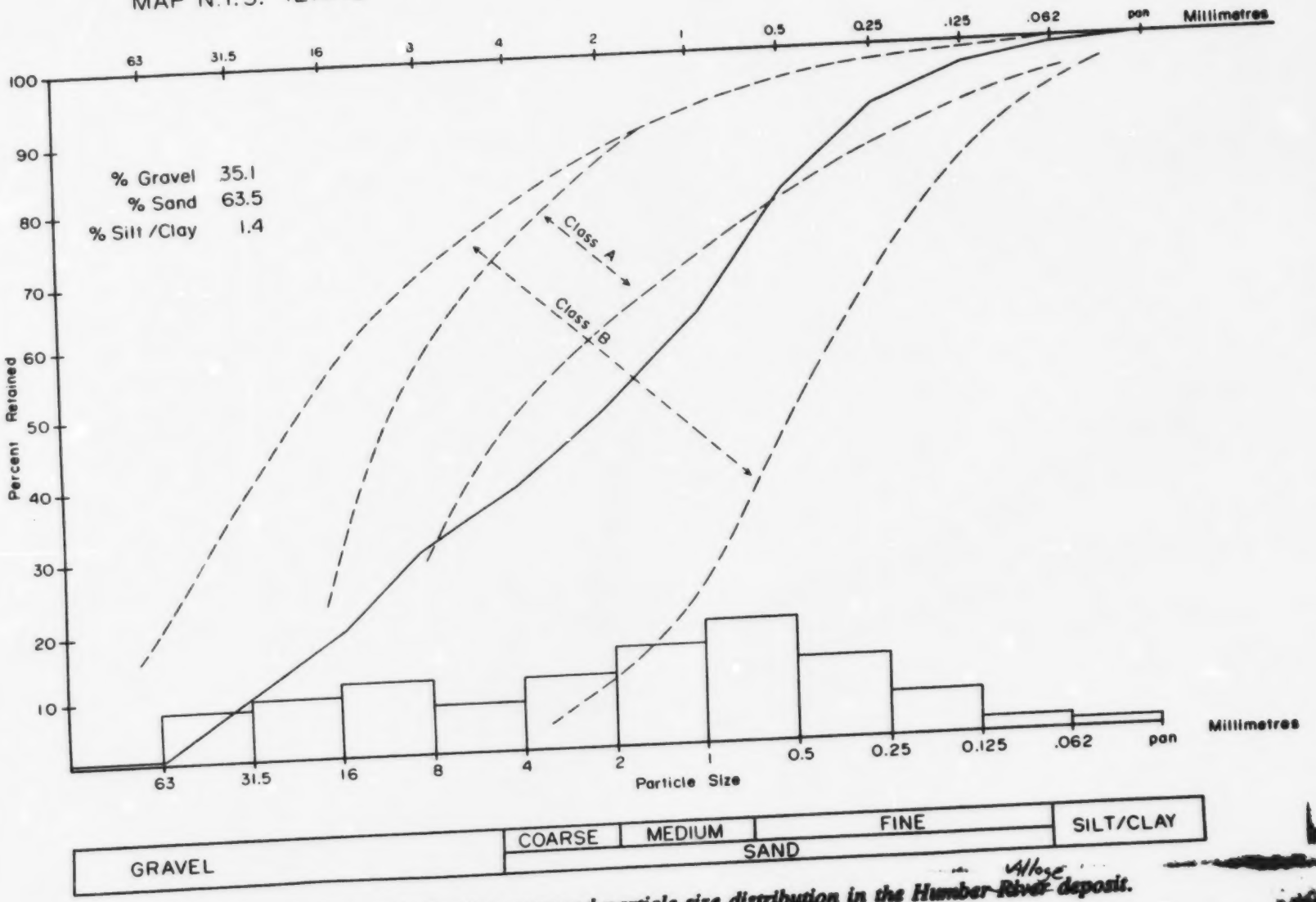

Figure 3. *Cumulative graph showing averaged particle-size distribution in the Humber ~~River~~ Village deposit.*

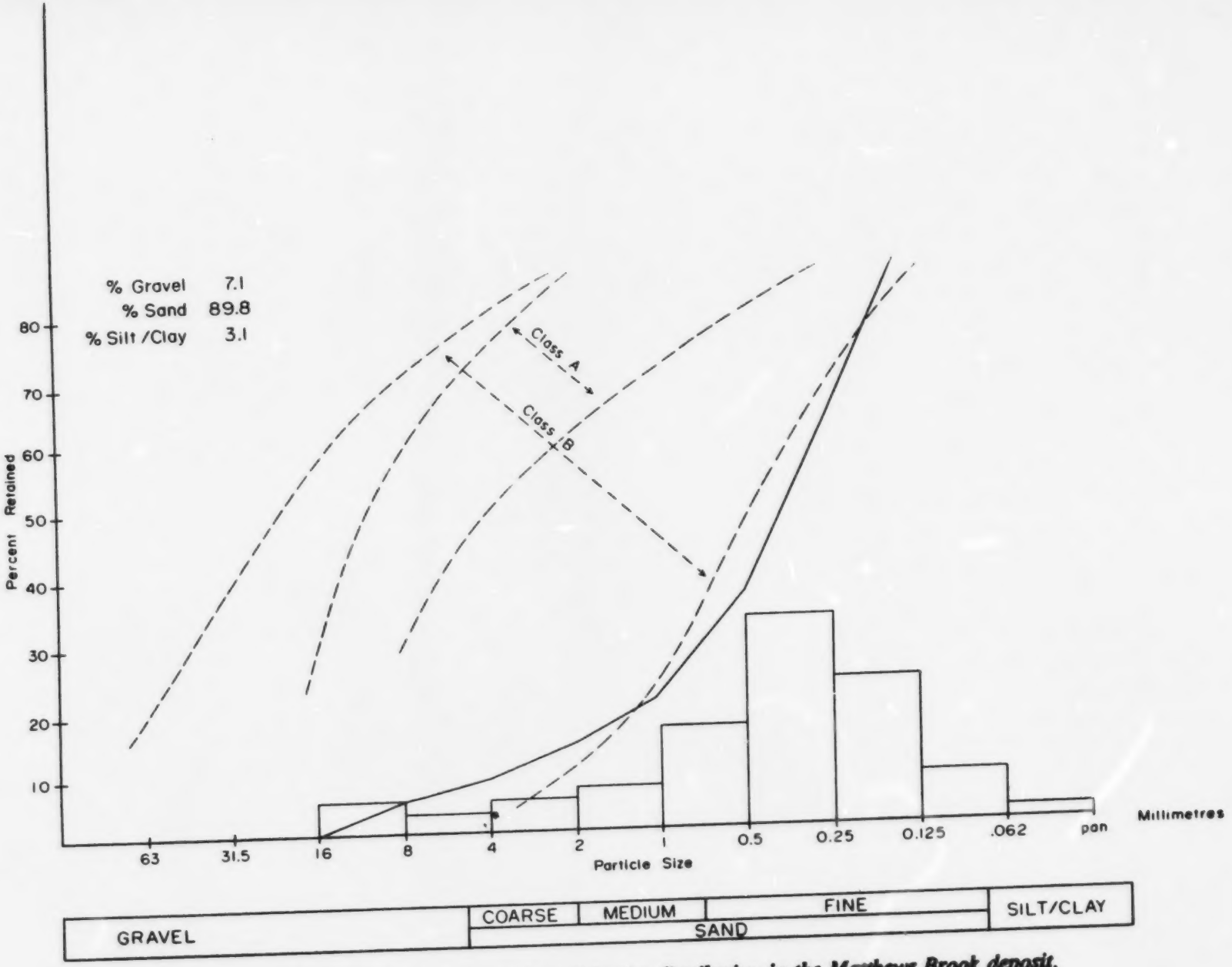

Figure 4. *Cumulative graph showing averaged particle-size distribution in the Matthews Brook deposit.*

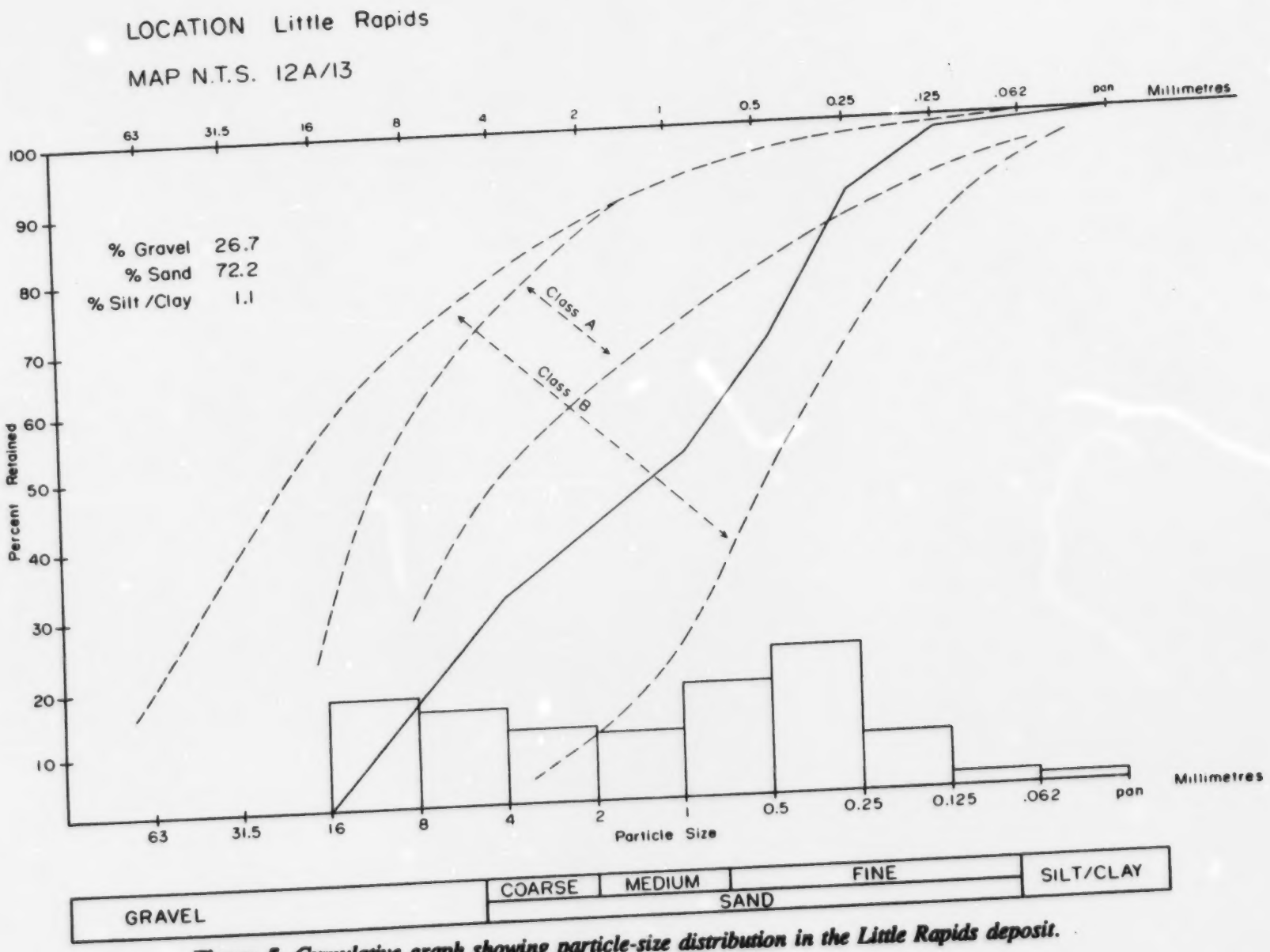

Figure 5. *Cumulative graph showing particle-size distribution in the Little Rapids deposit.*

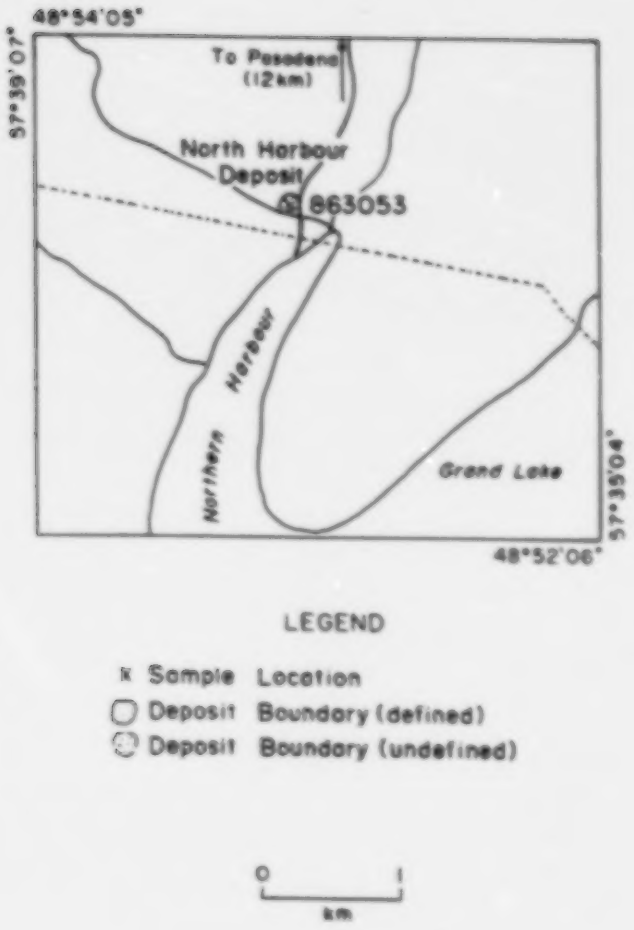

Figure 6. *Silica-rich sand deposit near North Harbour.*

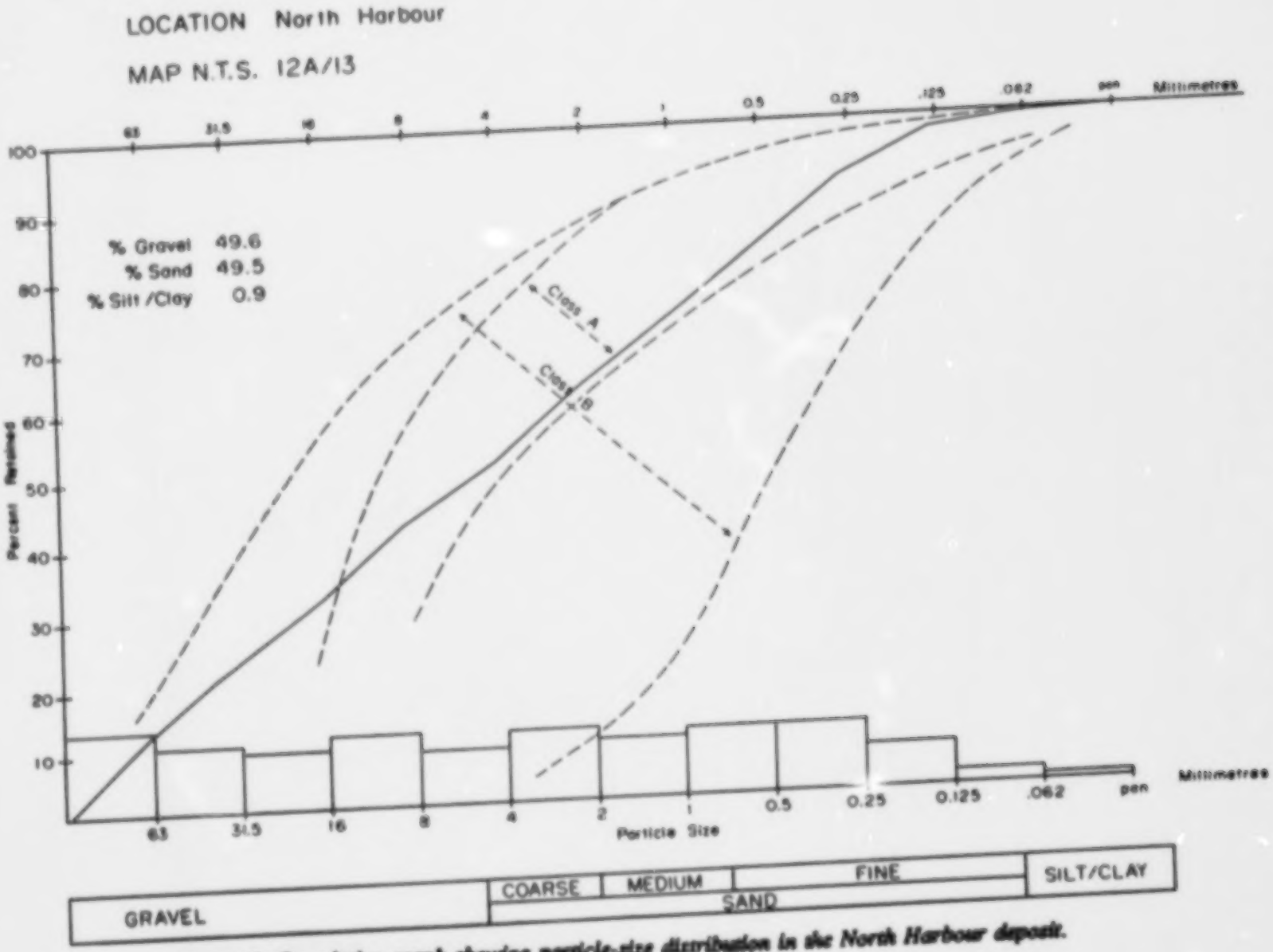

Figure 7. *Cumulative graph showing particle-size distribution in the North Harbour deposit.*

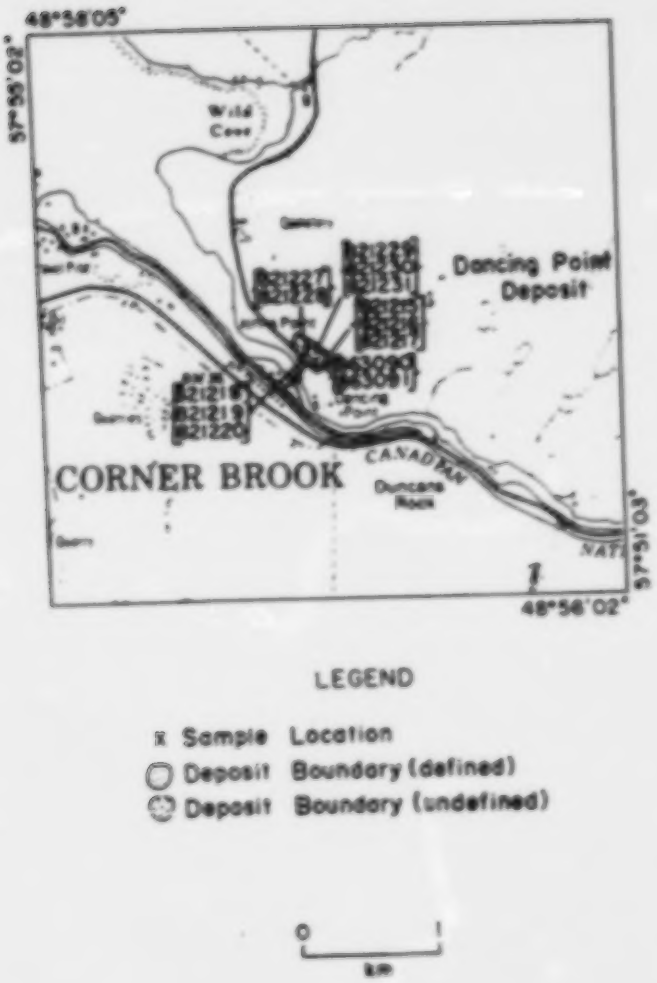

Figure 8. *Silica-rich sand deposit near Dancing Point.*

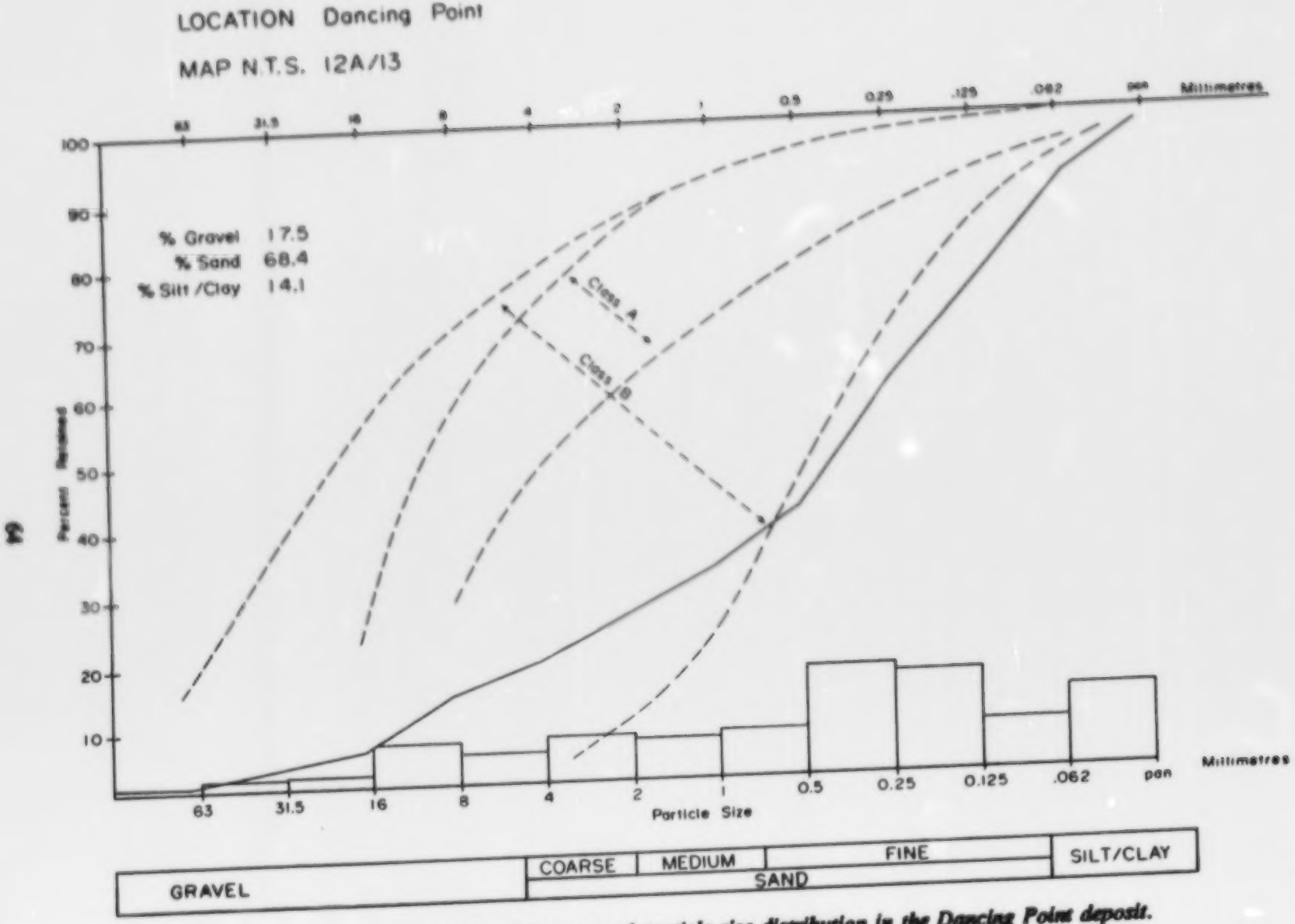

Figure 9. *Cumulative graph showing averaged particle-size distribution in the Dancing Point deposit.*

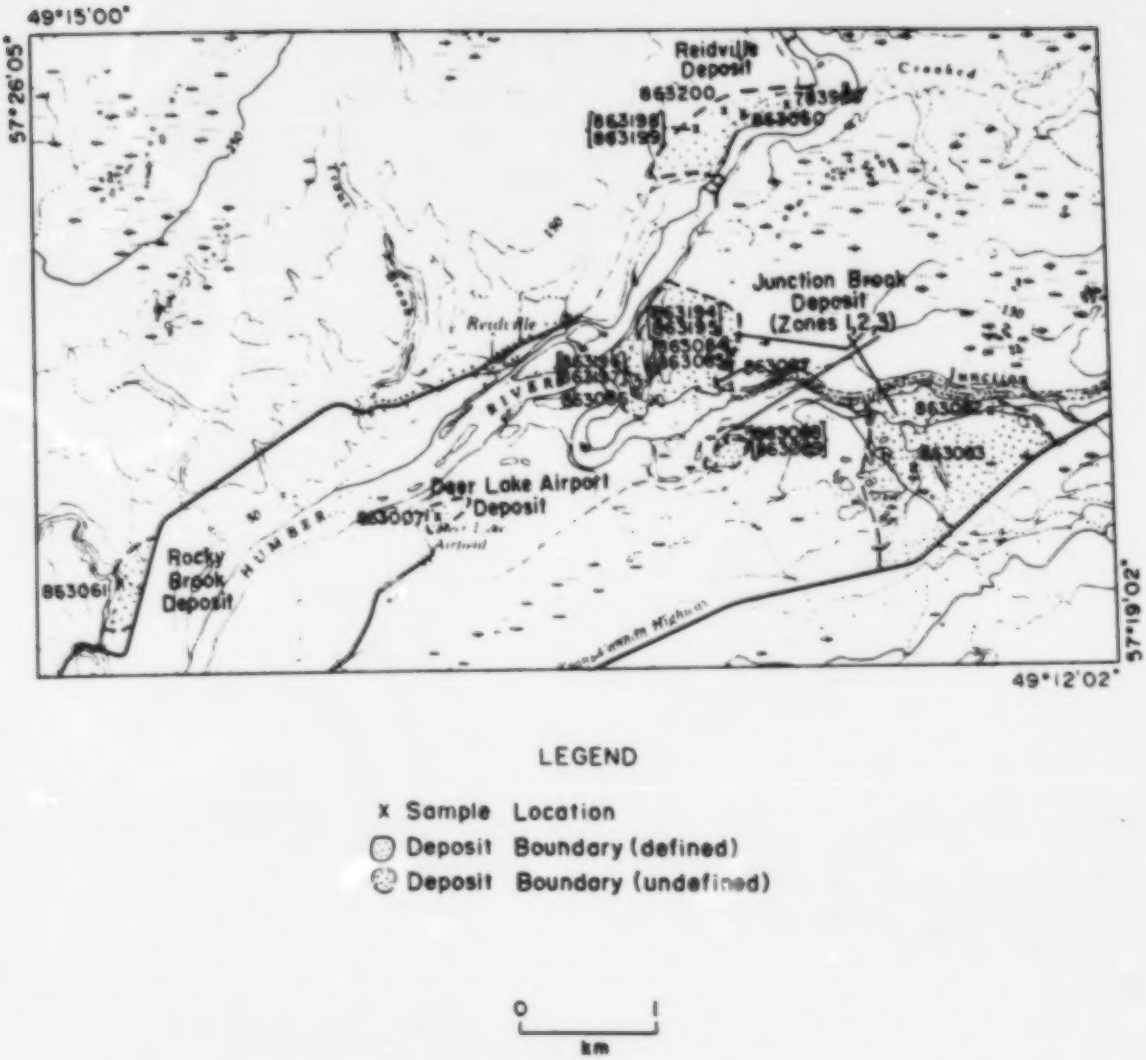

Figure 10. *Silica-rich sand deposits near Reidville, Rocky Brook, Junction Brook and the Deer Lake airport.*

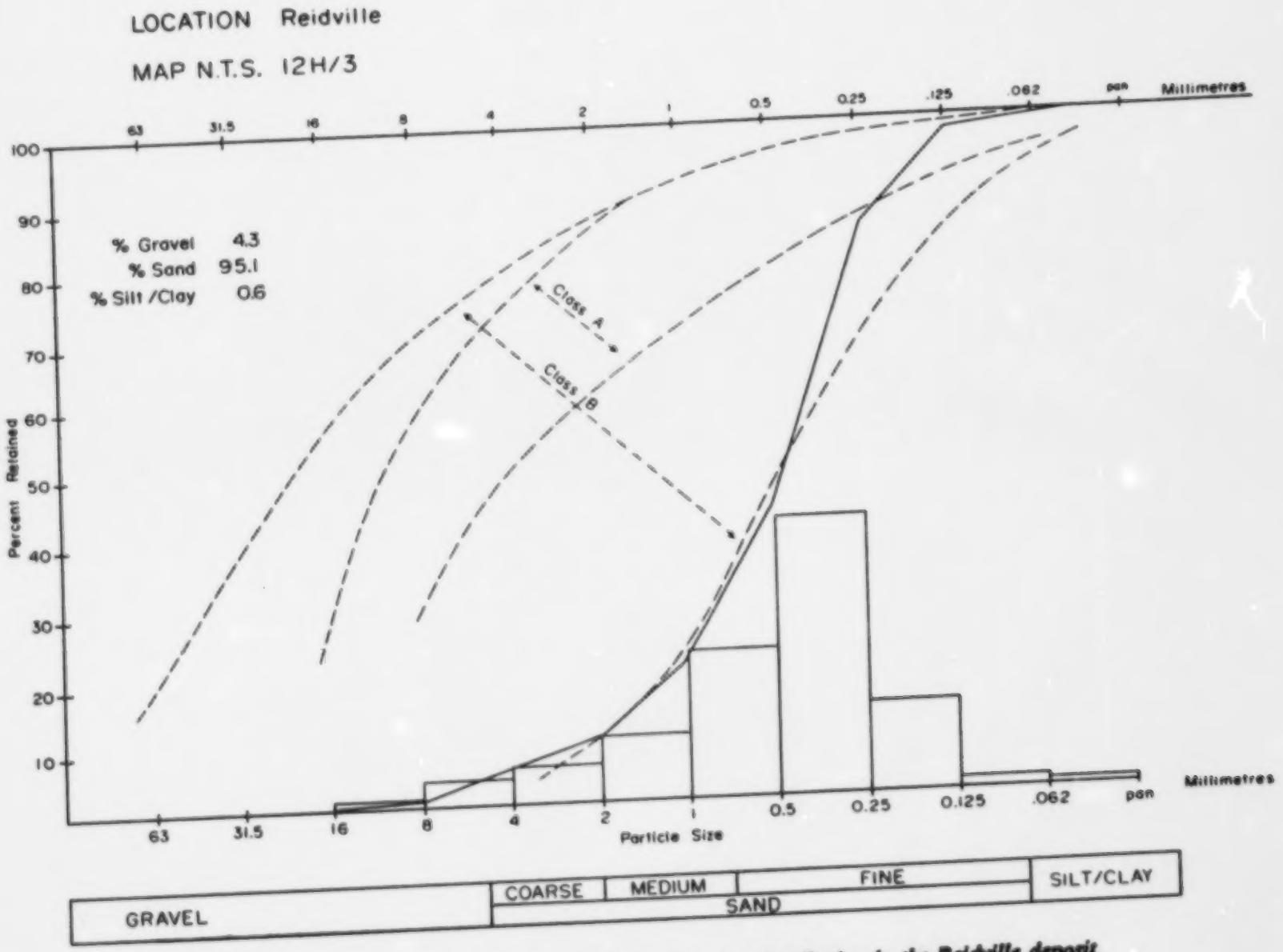

Figure 11. *Cumulative graph showing averaged particle-size distribution in the Reidville deposit.*

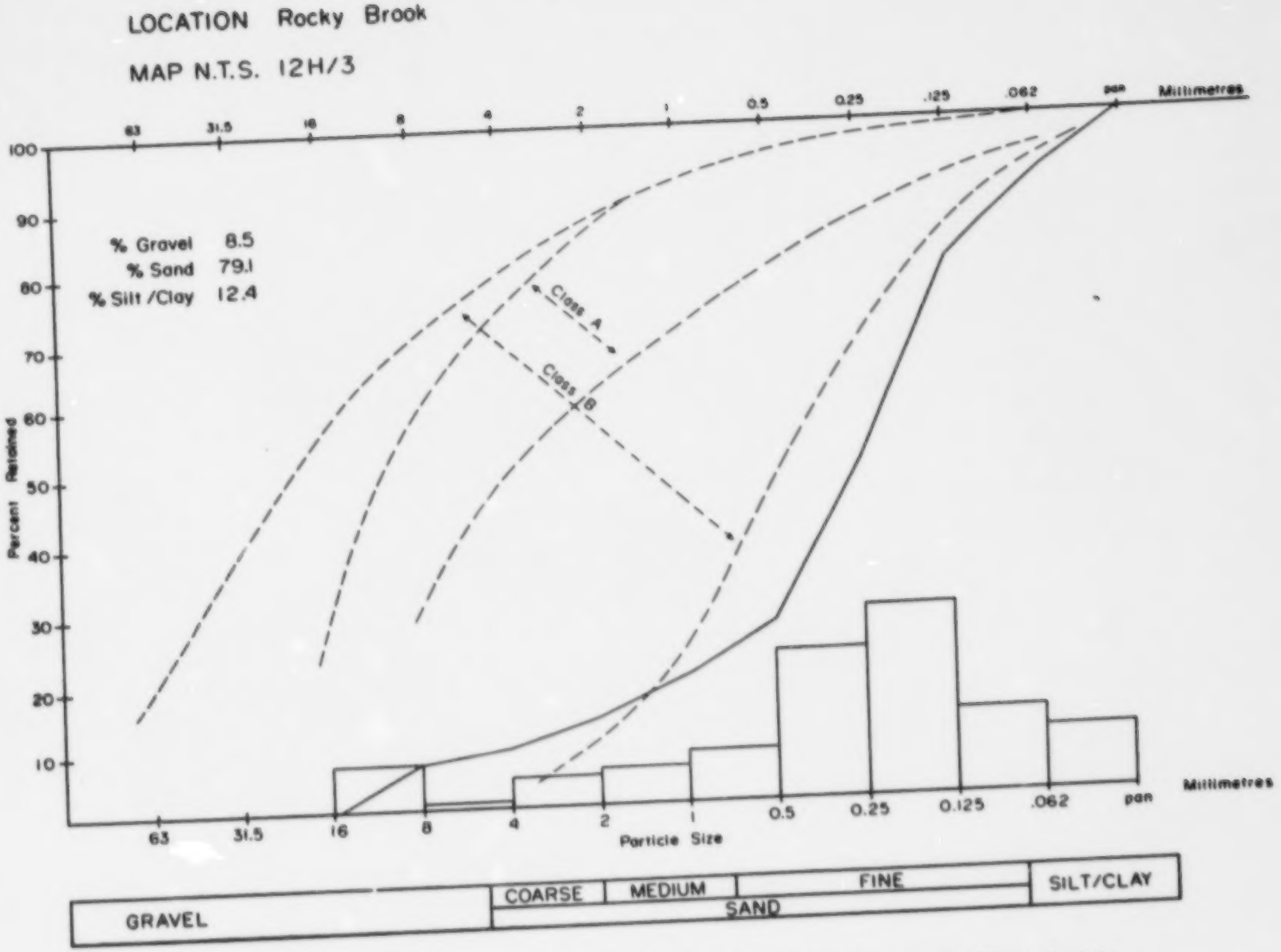

Figure 12. *Cumulative graph showing averaged particle-size distribution in the Rocky Brook deposit.*

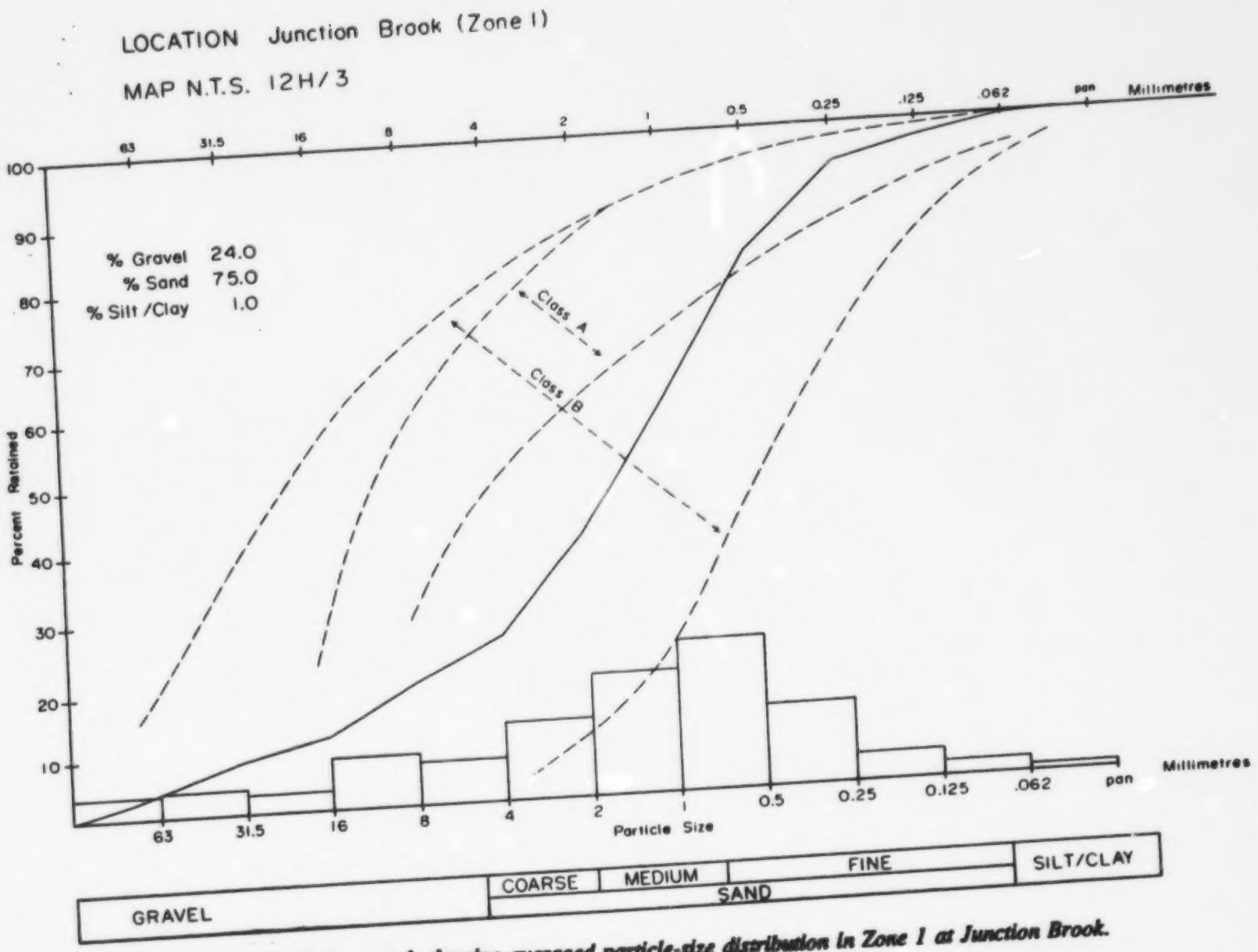

Figure 13. Cumulative graph showing averaged particle-size distribution in Zone 1 at Junction Brook.

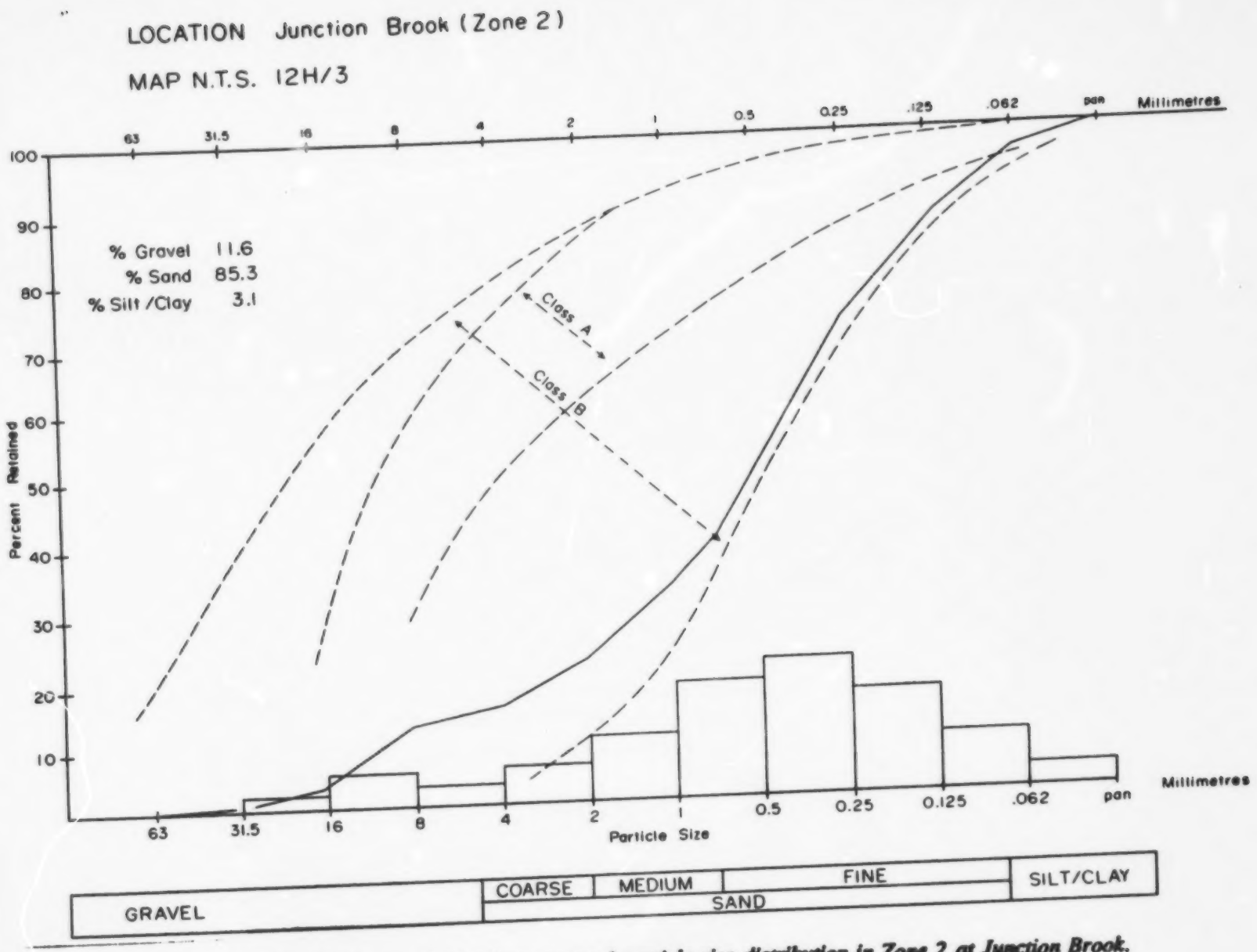

Figure 14. ***Cumulative graph showing averaged particle-size distribution in Zone 2 at Junction Brook.***

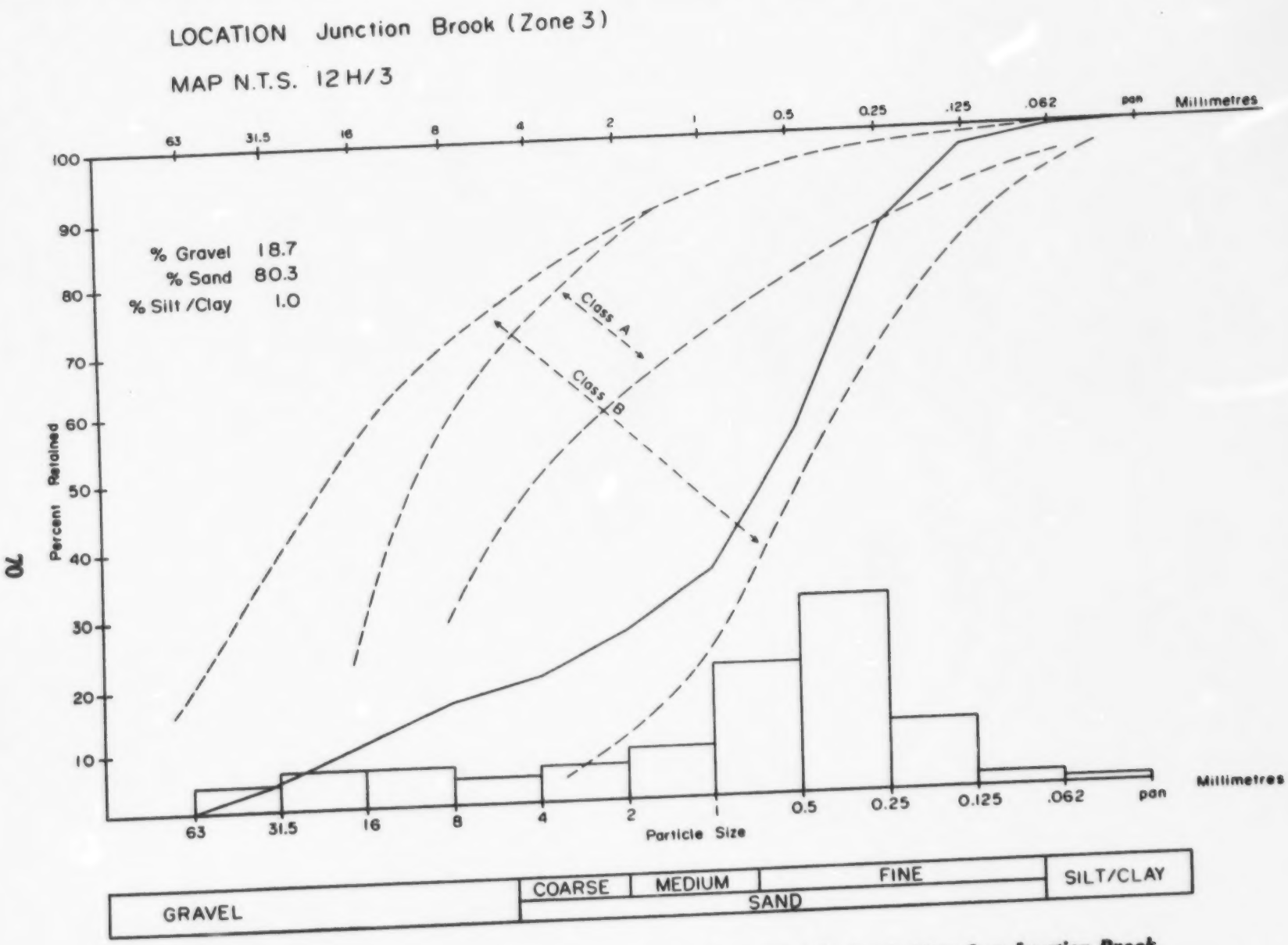

Figure 15. ***Cumulative graph showing averaged particle-size distribution in Zone 3 at Junction Brook.***

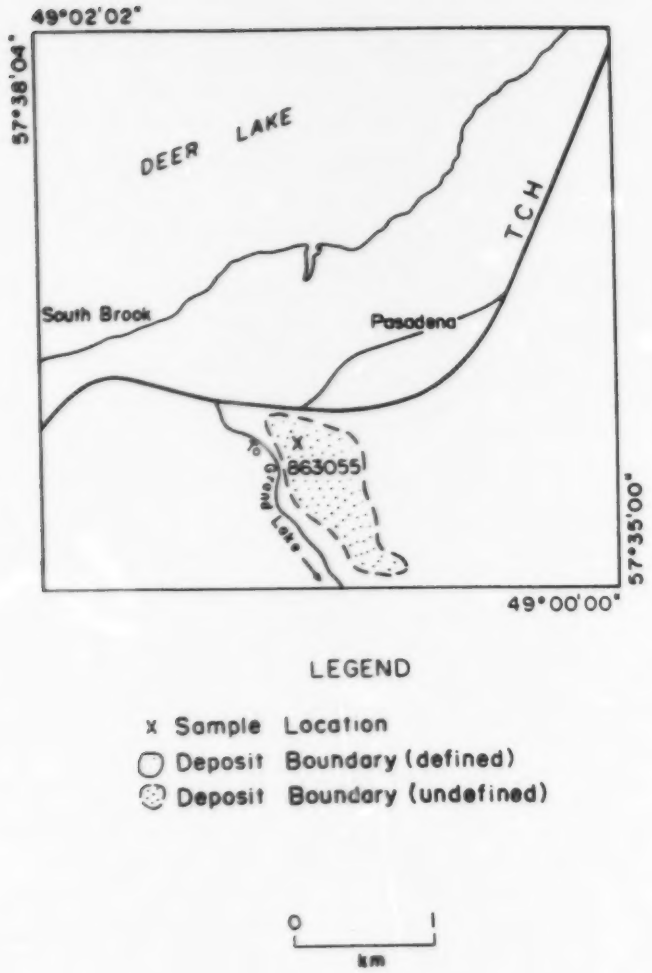

Figure 16. ***Silica-rich sand deposit near Pasadena.***

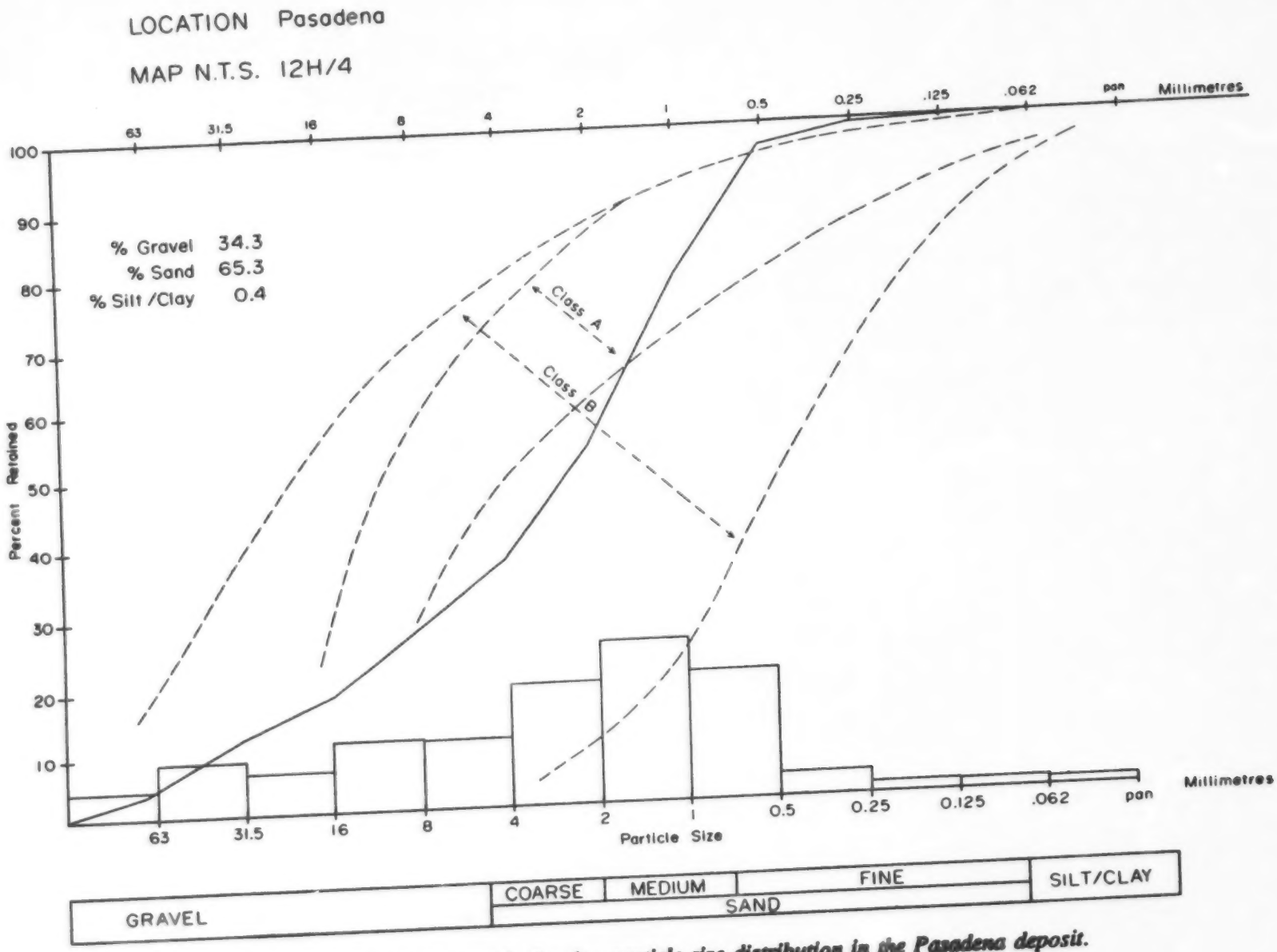

Figure 17. *Cumulative graph showing particle-size distribution in the Pasadena deposit.*

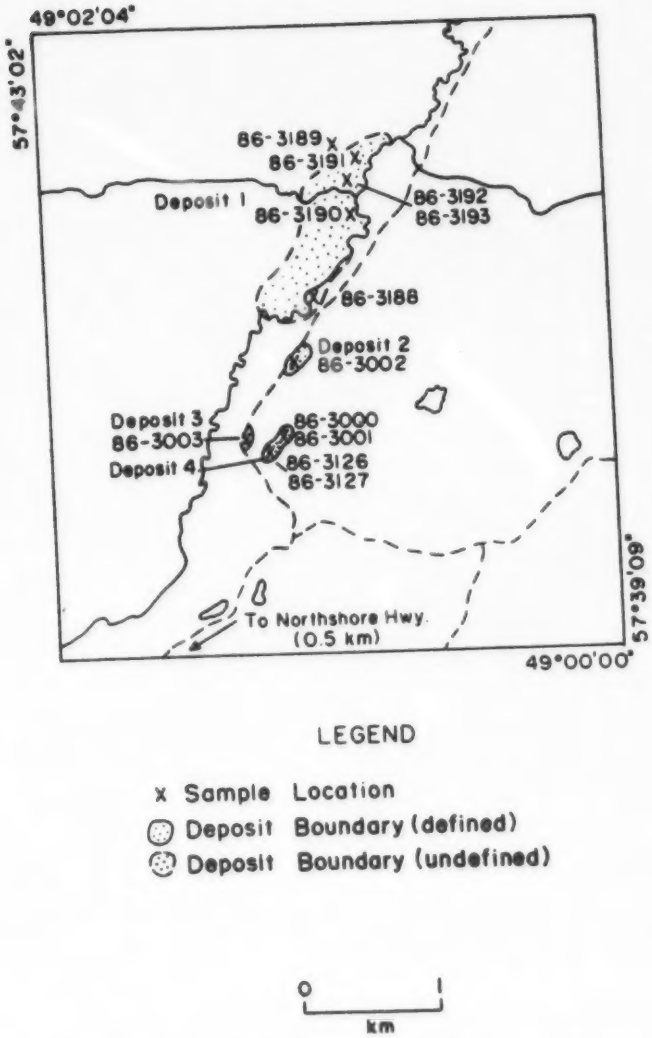

Figure 18. ***Silica-rich sand deposits at Hughes Brook.***

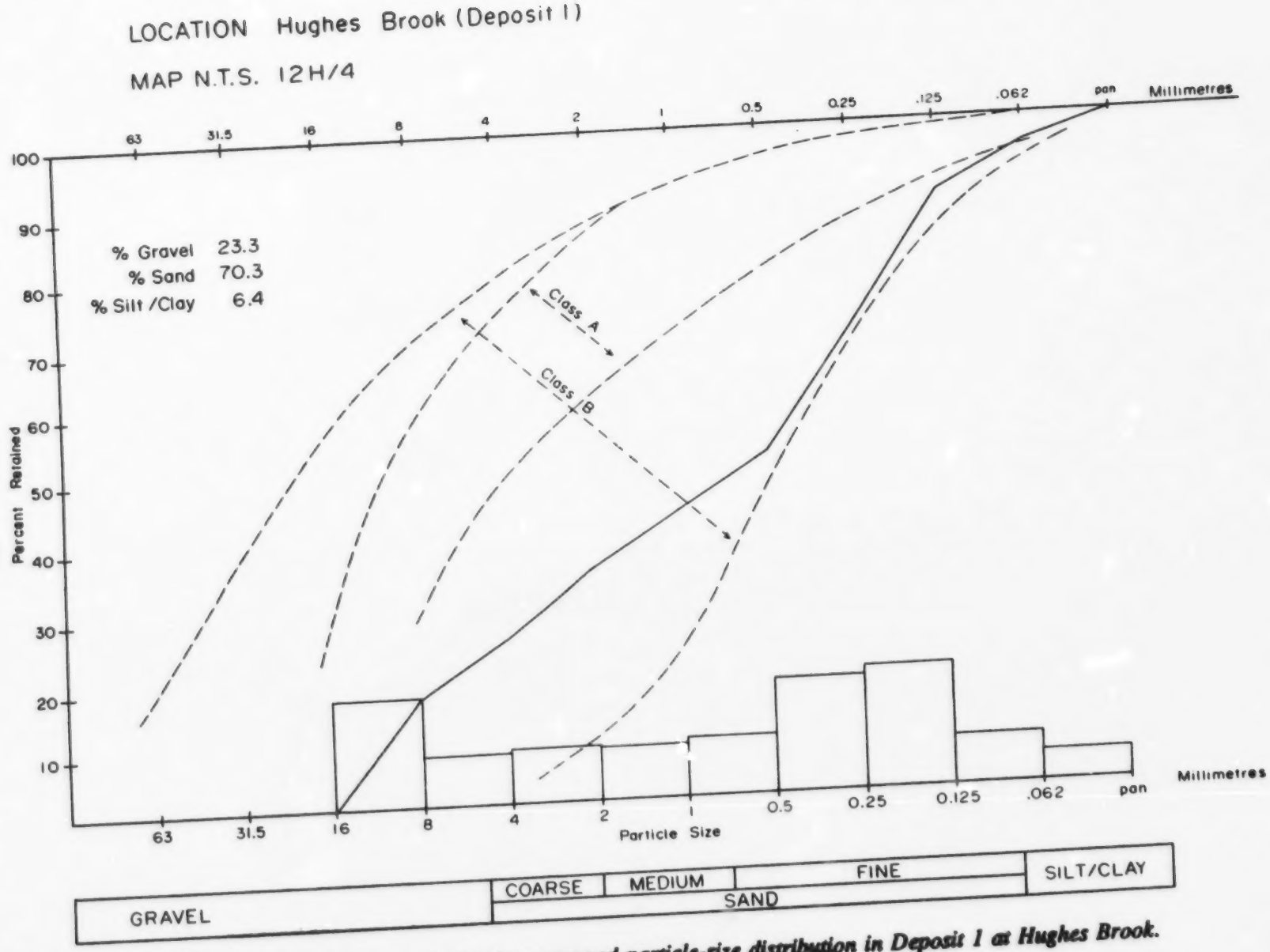

Figure 19. *Cumulative graph showing averaged particle-size distribution in Deposit 1 at Hughes Brook.*

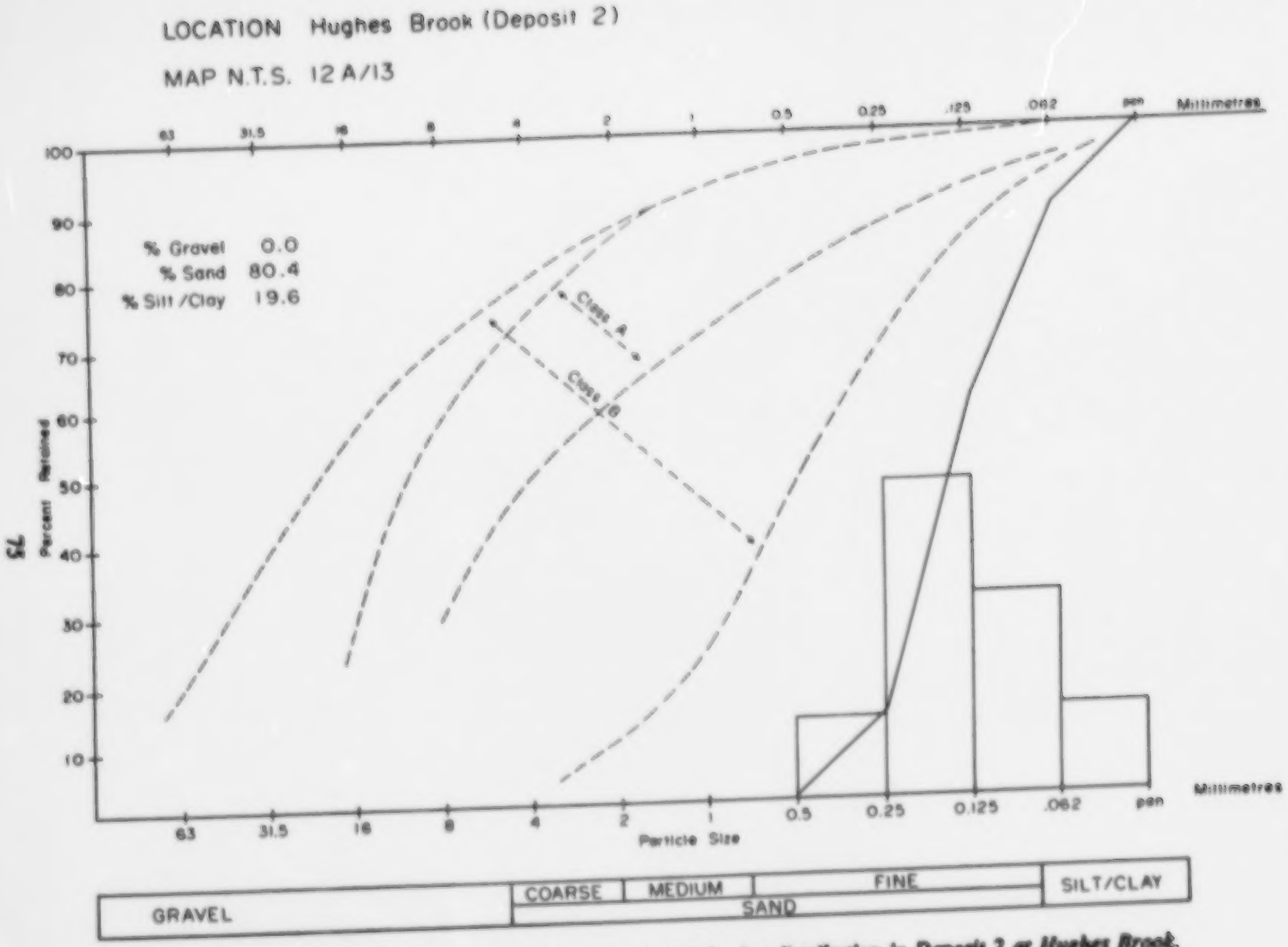

Figure 28. *Cumulative graph showing averaged particle-size distribution in Deposit 2 at Hughes Brook.*

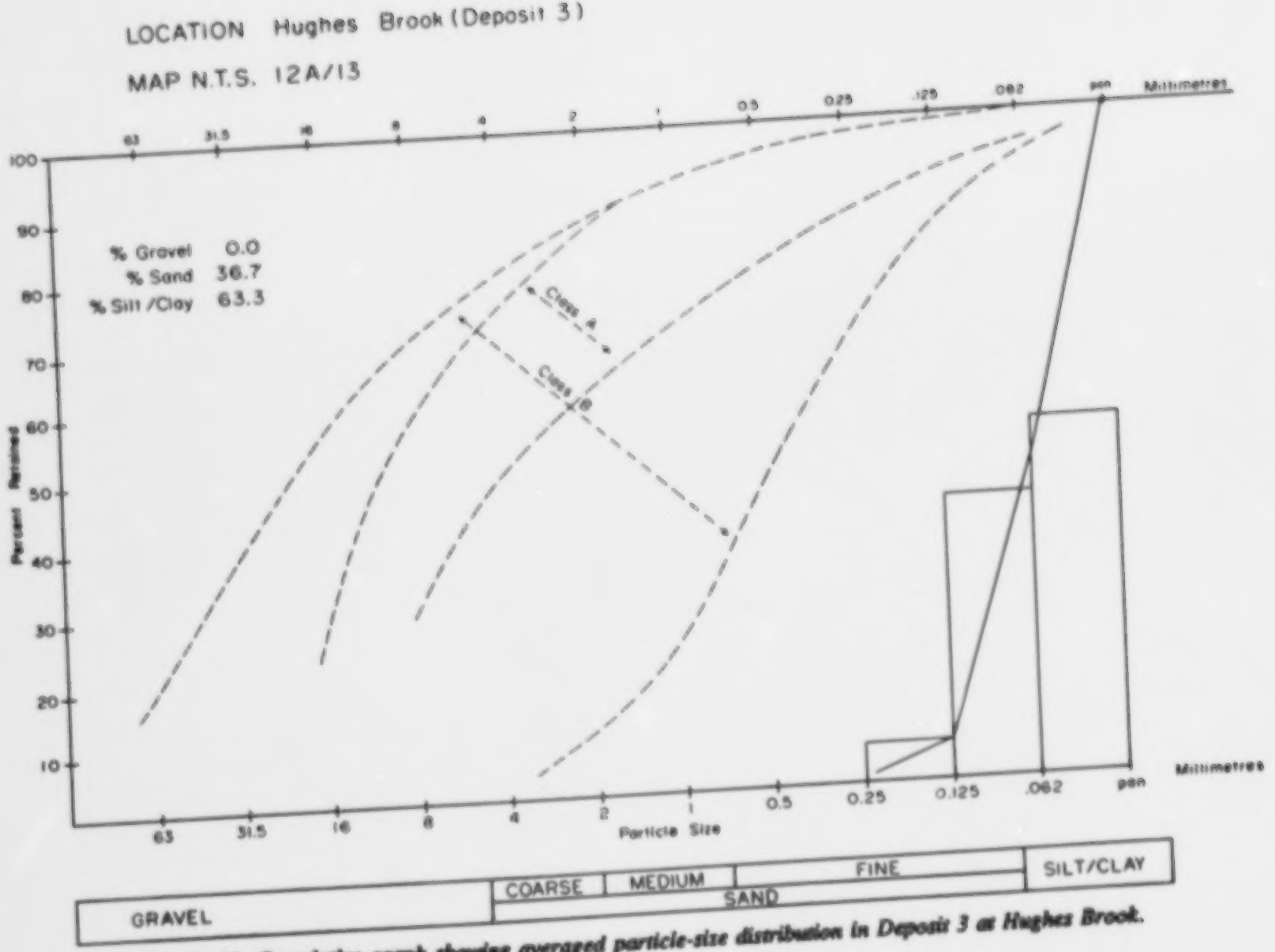

Figure 21. *Cumulative graph showing averaged particle-size distribution in Deposit 3 at Hughes Brook.*

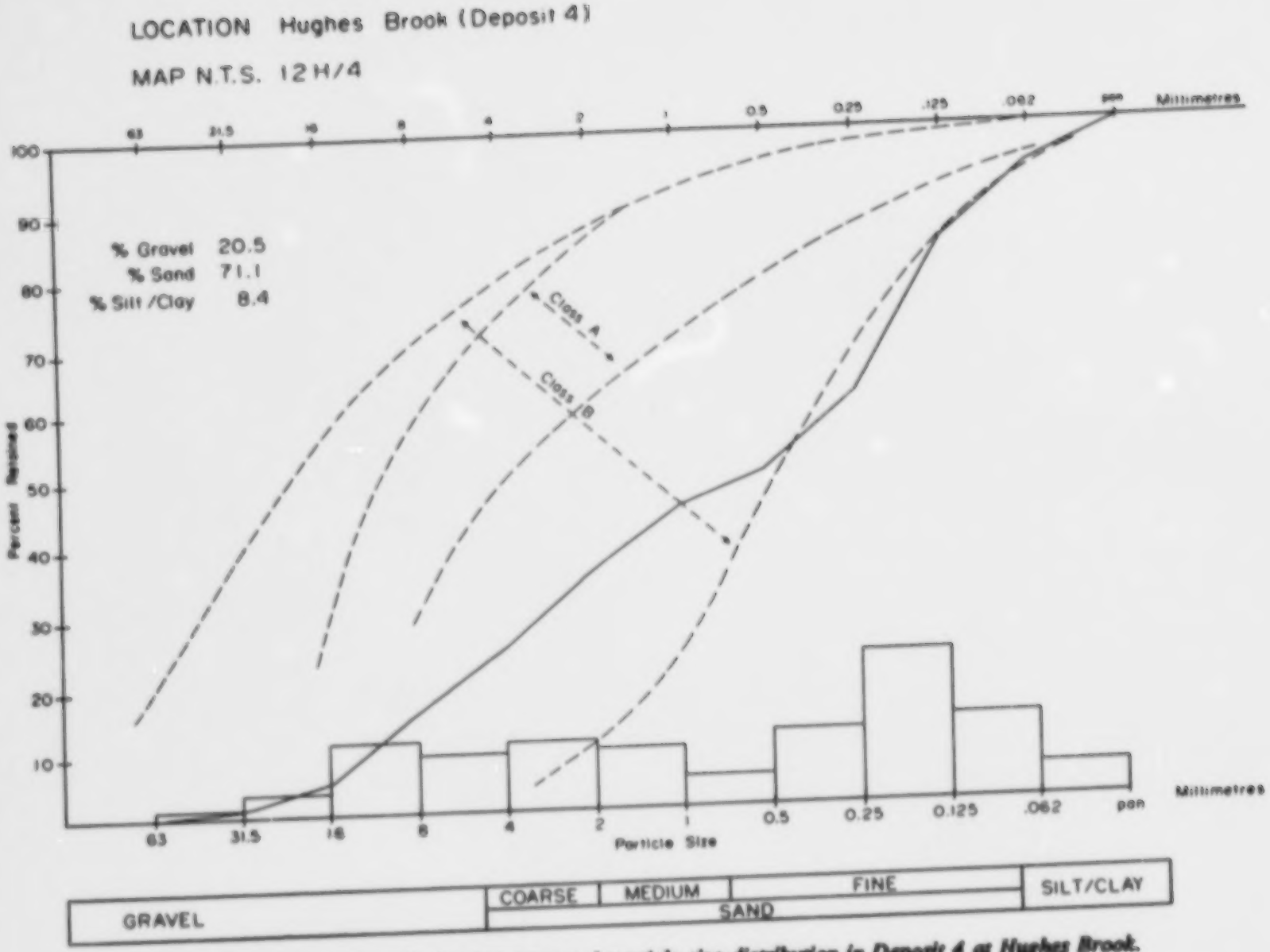

Figure 22. *Cumulative graph showing averaged particle-size distribution in Deposit 4 at Hughes Brook.*

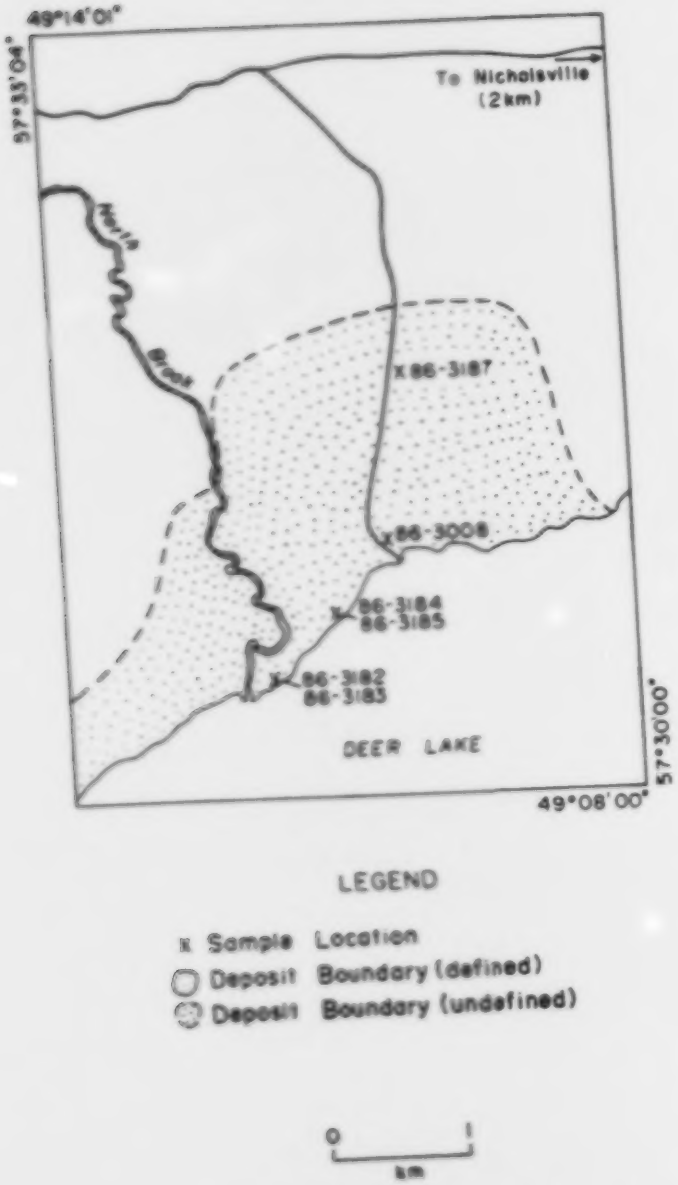

Figure 23. *Silica-rich sand deposit at North Brook.*

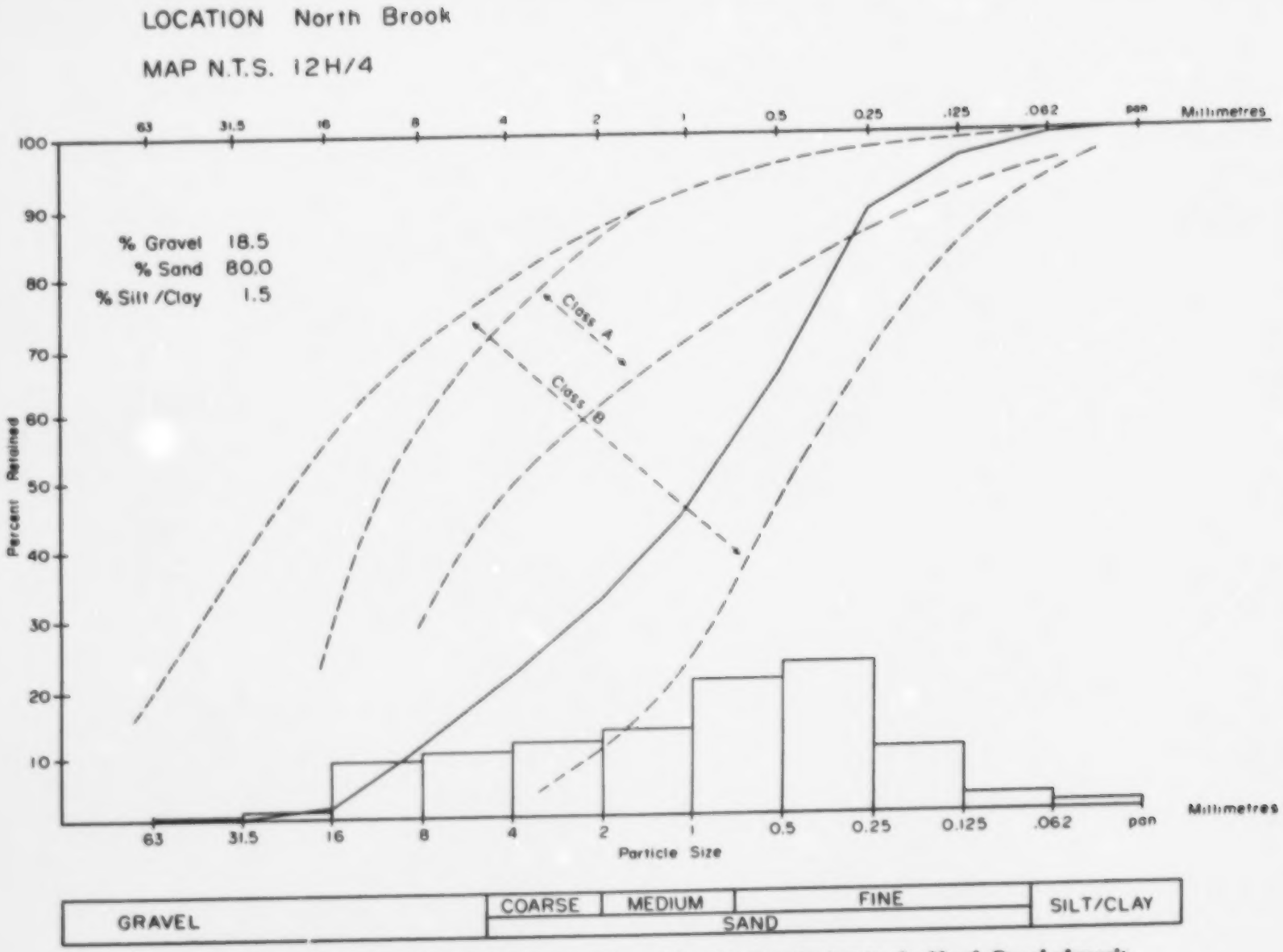

Figure 24. *Cumulative graph showing averaged particle-size distribution in the North Brook deposit.*